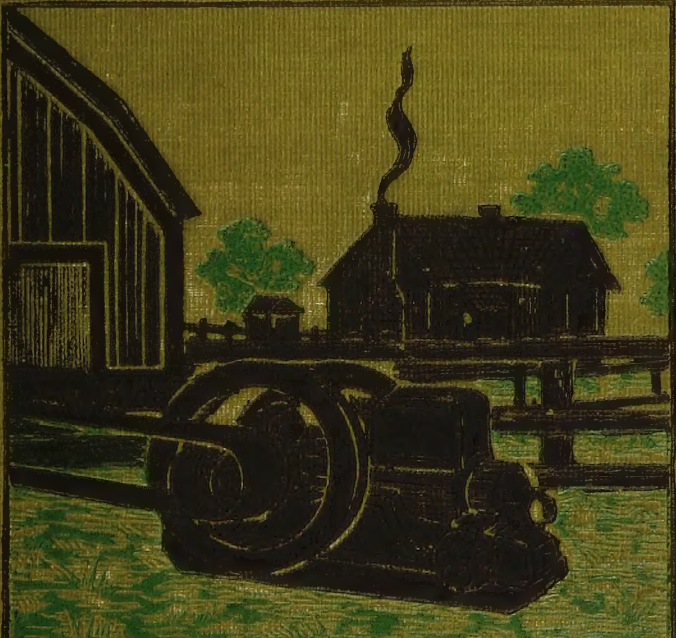
THE GASOLINE ENGINE ON THE FARM

CONSTRUCTION, MANAGEMENT, APPLICATION, OPERATION AND REPAIR



XENO W. PUTNAM

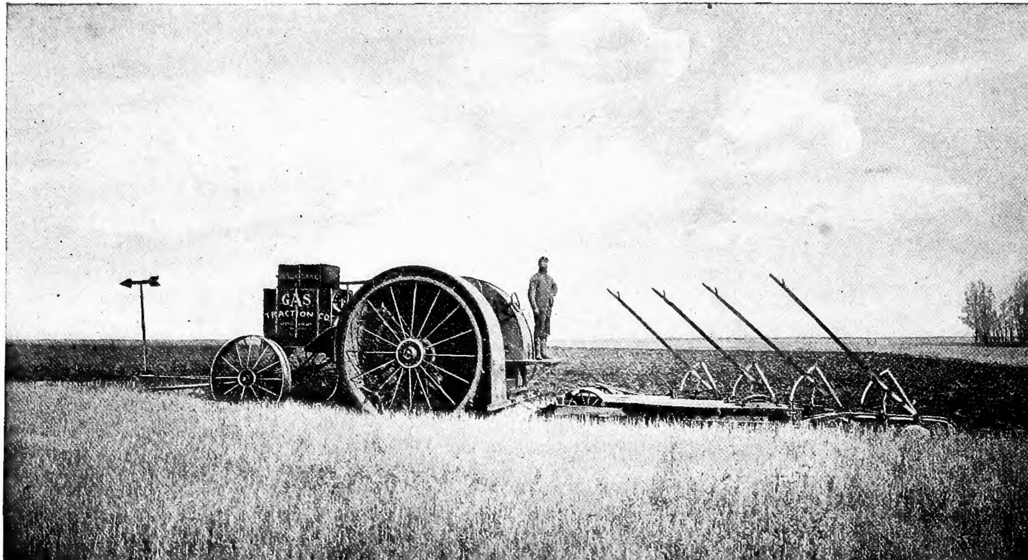


FIG. 1.—FRONTISPIECE.—Gas Tractor Doing the Work of Forty Horses and Twenty Men.

THE GASOLINE ENGINE ON THE FARM

A Practical, Comprehensive Treatise on the Construction, Repair, Management and Use of this Great Farm Power as Applied to All Farm Machinery and the Farmer's Work Indoors and Out

THIS TREATISE, BECAUSE OF THE SIMPLE, NON-TECHNICAL EXPOSITION OF MECHANICAL PRINCIPLES, IS ESPECIALLY VALUABLE TO THOSE WITHOUT PREVIOUS MECHANICAL KNOWLEDGE WHO WISH TO BECOME THOROUGHLY FAMILIAR WITH THE OPERATION AND CARE OF GASOLINE ENGINES, TRACTORS AND AUXILIARY DEVICES.

THIS IS A COMPLETE WORKER'S HAND BOOK ON THE INTERNAL COMBUSTION MOTOR AND ITS MANY APPLICATIONS IN MODERN FARM LIFE. CONSIDERS ALL THE HOUSEHOLD, SHOP AND FIELD USES OF THIS UP-TO-DATE PRIME MOVER AND INCLUDES CHAPTERS ON ENGINE INSTALLATION, POWER TRANSMISSION, AND THE BEST ARRANGEMENT OF THE POWER PLANT WITH REFERENCE TO THE WORK.

BY XENO W. PUTNAM

Fully Illustrated by 179 Carefully Selected Engravings of great value to all interested in the efficient and economical application of farm power.

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PREFACE

It requires the theorist's careful study to develop new inventions, even though accident may have first suggested them. It remains for the practical workman to adapt something that may have only great academic interest in practical work and thus obtain results that make the new discovery of world-wide value. The formulæ of philosophy are needed among engineers and scientists and should not be discredited or valued too lightly, but, at the same time, the workmen who apply the theory to practice require only the every-day language of the field in an exposition designed for their instruction.

The gasoline engine was, until recently, but a theory; it is now a completed fact and has been turned over to the result getter. It is doing the world's work everywhere. In many industries it is taking the place of other forms of power, but it is just entering into a mission upon the farm that has heretofore been unfilled.

With the coming of a prime mover that is really applicable to ~~the peculiar~~ conditions surrounding ~~the farmer's work~~, there comes a demand for men trained for the opportunity, capable of making the most out of that which was yesterday a dream and is to-day an achievement. The problems of the engine and its management will face the farmer of the future with the same imperative demand for their solution that now obtains regarding those incidental to the intelligent care and control of his live stock and agricultural machinery. They are facing him now and will continue to confront him until

he solves them and wins for human intelligence another triumph of magnitude.

This volume is intended for the workmen of the farm, to assist them in meeting a new condition; because of this purpose all technical statements of the laws of philosophy and exact science have been discarded wherever possible for simpler language and expression intelligible to those needing the information.

THE AUTHOR.

January, 1913.

ACKNOWLEDGMENT

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THE GASOLINE ENGINE ON THE FARM

CHAPTER I.

THE CALL AND THE ANSWER.

1. **The Great Farm Problem.**—The world is asking for bread and the farmer must supply it. For that purpose he cultivates his lands. The call of the farmer is for efficient helpers. There is a scarcity of workmen which is hampering him at every turn. It required 50,000 acres, some one has figured, to supply the meager necessities of a single savage, but less than twenty-five acres are available to supply the more exacting demands of each citizen to-day. Intensive culture alone can meet the demand; more work and better work on every available acre, and the call for extra helpers which cannot be answered with men must be met by machinery. The farmer of the future must be a mechanic rather than a day laborer. He will have time for little but the intellectual part of soil-tilling, while the manual labor will more and more of it be done with wheels and levers. Hand labor was long ago dispensed with in the mill and factory wherever possible because it is more expensive than the factory can afford. The farmer has adhered to the harder and more costly method and has performed work manually that some adequate farm power might have done better and cheaper.

2. **The Machine Designer's Problem.**—Many de-

vices that might have reduced the labor of the farmer have never been placed upon the market, because all farm machinery formerly had to be restricted to the limits of the horse in power and speed. In this respect the farm implement designer has been more seriously hampered than any other class of inventors. Without the aid of steam and electricity our factories would still be in their infancy. How much the world has lost through its most important industry, agriculture, because of this unfortunate limit placed upon her field appliances can only be guessed at. Many valuable inventions have been abandoned because they had to be made too light or too slow for effective work, in order that they might be handled by the ordinary farm team.

3. **The Call of the Farm.**—The call of the farm is for power; some means by which the intelligence of a single man can direct a force that will do as much work as a dozen or a hundred men could do with their unaided hands. Farming has indeed advanced from the plane of simply making a living to that of a great commercial project. From plowing to shelling, it takes four and one-half hours' work to raise one bushel of corn by hand. Machinery and power reduce this to forty-one minutes. The same commercial arguments which demand power in the factories render it even more necessary upon the farm.

4. **Other Forms of Power and Where They Fail.**—Various forms of farm power have been tried and have failed. The tread-mill was not a real power, but a clumsy means of transmitting the limited energy of some animal. It was unsteady, hard to operate, and soon became a synonym for drudgery. Sweep power is hard to move, cumbersome, and usually requires the exposure of its operators to every storm. The

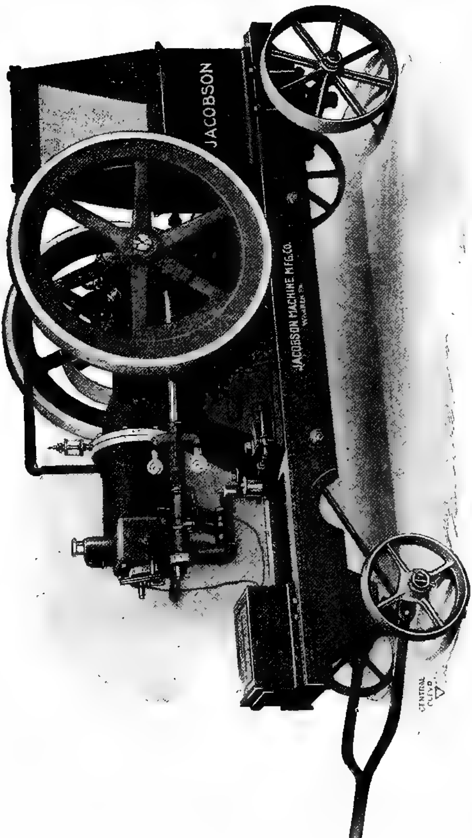


FIG. 2.—The Portable Gas Engine Solves the Problem of Practical Farm Power.

water wheel is of very restricted application. It may easily fail in dry weather and, at best, cannot be moved about. Wind mills are objectionable for the same reason; also from the unreliable nature of their motive force. Steam alone has been the only serious competitor of the horse in general farm work; still it is not by any means the ideal farm power.

5. **The Ideal Farm Power.**—Much of the farmer's work is done in short runs and at many different places. His ideal power must be ready at a moment's notice and must not cost anything to maintain except while in use. It must be safe, reliable, easy to operate and portable; not easily disturbed by weather conditions; available at any place, indoors or out. Electricity might avail for all of this excepting portability, were it more generally to be obtained upon the farm. It usually is not, unless produced by the borrowed energy of steam or gasoline engine at a good deal of waste in transmission or in transforming mechanical to electrical energy.

6. **The One Best Answer.**—The gasoline engine is the only power at the present time that has answered all of these various demands. It is a wonderfully flexible power, adapting itself to all conditions. While the teams are being fed the engine may be started upon a day's run at the feed mill; then the operator is free to go back to breakfast. No fuel is being used, as is the case with a steam boiler, while steam is raised. The operator needs no greater mechanical training than should be considered necessary to properly run a binder. If power is needed in the kitchen to operate the washing machine two men can pick the engine up and take it there. If wanted in the farthest corner of the wood lot it can be set on the farm wagon and conveyed there without the neces-

sity of a second or third trip for water tank and fuel; neither is there a trail of feed-wires to erect. The driest and calmest weather does not disturb it, nor does it break away from its moorings in the fiercest wind. It can be obtained in 1/4 horse power sizes if required, while five thousand horse power engines are in successful operation. It works properly in zero weather or excessive heat and functions no matter what the mercury registers.

FIG. 3.—The Call of the Field for Power Best Met by Modern Gas Tractor.

7. **What It is Actually Doing in the Field.**—The most convincing argument in the world is achievement. Let us see what the gasoline engine has actually done; what it is now doing on the farm. In parts of the West where best known, it is driving the steam tractor from the field; is plowing, harrowing and seeding all in one operation, by the square mile instead of by the acre, and is doing the work better, as well as quicker and cheaper, than horse power can do it. It is harvesting the grain when the fields are too soft to carry the ordinary binder and when the

steam tractor would be helpless; then, after threshing, it is conveying a part to market and converting the balance into the most available form for feeding cattle. It is loading hay in the fields and then unloading it in the barns or placing it in stacks. Without fear of hunger or thirst, it turns away from its source of supplies and requires no procession of fuel and water wagons to follow upon its trail. If the season is short or the weather threatening, it turns the night into day with its own headlight and lives its working life in twenty-four-hour days as cheerfully as in periods of eight or ten. Where necessary it has run without stopping from Monday morning until Saturday night with hardly an hour's attention during the entire time.

8. **As General Utility Man.**—The gasoline engine is irrigating fields and putting on the finishing touches of success where drought and failure threatened. It is annually saving to the world thousands of dollars worth of fruit from the ravages of fungus and insect. It is digging the farmer's post-holes; it is cutting his wood and hauling it to the sheds. It is taking out of farm life much of that drudgery which destroys human life more through dreariness than through expended energy. Perhaps its greatest value is in the every-day, humble occupations, and from these it never shirks.

9. **In the Kitchen.**—Unlike the general run of labor-saving implements, the work of the gasoline engine is not completed in the field. It runs the washer and wringer for the housewife with ease, pumps the water for her, does the churning, skims the milk, and has even been known to sweep the floor, clean the carpet, wash the windows and the dinner dishes. In numberless ways, after doing the heavy

field work, it has lightened the burden for some tired or semi-invalid housewife and added that touch of leisure or of beauty to the house or lawn so dear to the heart of the farm girl.

10. **With the Boy of the Farm.**—Between the gasoline engine and the boy of the farm there seems to be a special bond of sympathy that removes from the latter those terrors of wood-pile and grindstone that drove his older brother from the farm. It silences the call of the city by rendering farm life the more attractive of the two. The boy is progressive unless his ambition is crushed out with hard work. His school life feeds his ambition and the farm must either keep up with his love of progress or he will grow away from it. The engine is the boy's confidant and friend, for it develops in him that love of machinery upon which is based the world's achievements.

11. **The Hired Man Problem.**—Modern farm work has outgrown the capacities of a single pair of hands. The hired man is a necessity; but where the number of places needing him is so greatly in excess of the supply of desirable men, it is but natural that the farm which is best equipped for the elimination of drudgery is most attractive to the most progressive men. The engine is making it more desirable by making it more efficient; by shifting the drudgery of physical routine to the alertness of applied intelligence; for drudgery always dulls the intellect and produces the lowest form of efficiency.

12. **The Greatest Mission of All.**—The gasoline engine has done all this; it is doing still more. Many of to-day's important industrial problems originate upon the farm and depend upon its productiveness, its extension, and its life for their solution. As the proportion of workers remaining on the farm becomes

less, their importance to those who have left it becomes greater, and nothing raises the standard of civilization in any community so quickly as a decrease in the cost of power; a conserving of human life by surrounding its workers with better conditions, which have been robbed of drudgery and no longer dwarf the intellectual man. The highest form of conservation applies to the world's men and women more than to her raw material. Manual labor has become too slow

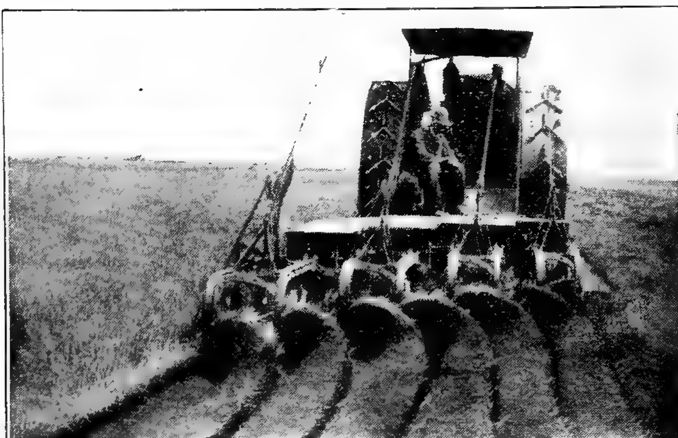


FIG. 4.—The Man With the Hoe of To-day.

and it accomplishes too little; it cannot keep up with the demand. The only true economy in the use of human energy lies in putting it to some more productive work than that a machine can do as well and twenty times as fast. The true place for the man himself is at the controlling lever, where more than automatic machine action is needed and where human intelligence rules supreme. This wonderfully universal and flexible power is placing the modern

farmer's work on a higher plane and is turning former hit-or-miss methods of farming into a definite science.

In its one expression, the automobile, it has given farm intelligence its rightful place in the social world. It has broken down the false and undesirable social barriers that formerly existed between town and country life and which, in a great measure, have been responsible for the unpopularity of farm life among both city and country young people. To-day the best schools and lecture halls are placed within reach of the farm door and country youth, surrounded at last by environments it craved, has made the most of them. After the hour of intellectual enjoyment they return to the farm still loyal to it, but with new ideals and a broader appreciation of life.

The farm house itself, stripped of its atmosphere of drudgery and grinding toil, becomes an actual home where culture is no longer impossible. Out of the added leisure springs an influence of affection and respect that makes the man live a better life because of the home life from which the boy received his training.

CHAPTER II.

THE INTERNAL COMBUSTION ENGINE.

13. **The Principle.**—An ordinary shot gun, at the moment of discharge, delivers a pressure of about fourteen tons against the load before it. If we multiply this pressure by the length of the barrel—that is, by the distance through which the pressure is exerted—we have the working energy that the gun can deliver from one impulse. Three hundred such impulses a minute would multiply the amount of working energy or power by that amount. It is probable that the gun, in one of its earlier types, was the first internal combustion engine ever put to practical use. Such a destructive force could not be applied to machinery, but it set men to thinking that the principle so powerful in the destruction of life might be made to aid in more peaceful occupations.

14. **The First Engine.**—Two hundred and fifty years ago the Abbé d'Hautefeuille, a French chemist, began to develop the idea and, about 1680, an engine of this sort was actually built. It was not a success, for it required delicate mechanism to feed solid powder in suitable amounts and at regular intervals to the combustion chamber, and the grease, soot and sticky residue soon put this out of working condition.

15. **Other Attempts.**—Other attempts, usually with some explosive gas that could be more readily fed than powder, were experimented with, but it was not until 1860 that a practical working engine was brought

out. This was the Lenoir engine, in which many of the features used to-day had a rude beginning; but the expense of operating it was so great that its manufacture was soon discontinued. This, of course, was before the day of gasoline.

16. **The First Real Success.**—The Otto engine, brought out two years later by a young German, is generally considered the beginning of the gas engine industry, although, during the five-year interval between his first production and the engine that finally made him famous, several other styles, of greater or less merit, were announced. These partial successes, although crude and somewhat unreliable, convinced the world that there was an assured principle behind them and that the war implements of the past were indeed to be beaten into the plowshares of the future.

17. **What Internal Combustion Includes.**—All heat engines for which the heat is developed within the engine cylinder, instead of in a boiler or some outside receptacle, are internal combustion engines, whether the fuel used is gunpowder, gas, gasoline, kerosene or alcohol. For convenience all are usually called gas engines, and they differ little in construction aside from the variations required to get the different forms of fuel into the cylinder. Nearly all gasoline engines can be operated on kerosene by slightly changing the intake system; while the true gas engine differs hardly at all from the others except in substituting a device for mixing gas and air in place of the appliances required to convert the liquid fuels into vapor.

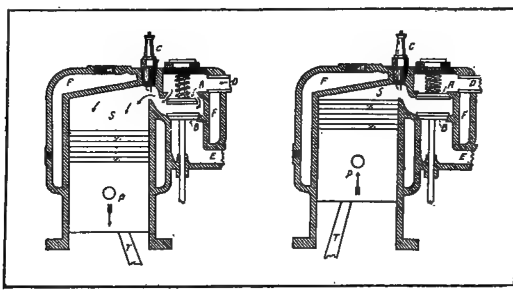
18. **The Real Source of Power.**—There is a common belief that the energy hurled against the piston of a gasoline engine acts as a baseball might act when thrown against some movable object. This is hardly the case. The impulse against the piston is due merely

to the expansion of gases under the intense heat generated by the sudden combustion, the temperature at that instant rising to between 2,000° and 3,000° Fahr., or enough to melt the iron walls if provision was not made for quickly cooling them. Only about twenty to twenty-five per cent. of this heat or thermal energy can as yet be directed into useful channels, the rest being wasted. In the use of steam, however, there is even a greater waste, while animal muscle, though it makes use of nearly fifty per cent. of its entire thermal energy during its working period, represents a continuous loss during idleness which brings the total waste up to even higher figures.

19. The Complete Cycle Explained.—Unlike the working energy of the horse, the gasoline engine produces its power in a series of sudden impulses, and, for each impulse, must accomplish four things: First the combustible vapor must be drawn into the cylinder or combustion chamber; second, this must be compressed; third, the compressed charge must be fired; and, last, the burned gases must be driven from the cylinder in preparation for the next charge of vapor. The complete process is called the cycle. Some engines accomplish this with one revolution of the crank, others with two. As perhaps eighty per cent. of all engines in use upon the farm are of the latter class, the actual working operations of the two-revolution, or four-cycle, engine will be first described.

20. The Four-Cycle Engine.—In the illustration (Fig. 5), the piston, P, is near the closed end or head of the cylinder, S; the exhaust valve, B, which opens inward, is shown as closed, and during the suction stroke is held shut by a heavy spring. (See top of cylinder, Fig 10.) As the piston descends it leaves a vacuum behind it; in other words, creates a suction

which causes the intake valve, A, to open and admit a charge of the fuel mixture through the intake pipe. The second or return stroke of the piston compresses the air and gas already admitted, closing the valve, A, and keeping it closed against the escape of the gas and so compressing or condensing the fuel mixture to the small chamber between the end of the piston at its highest point and the cylinder head. This is illustrated by Fig. 6.

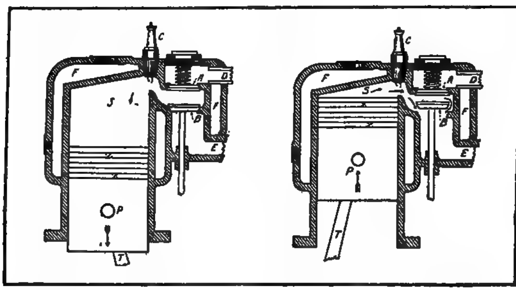


5 6

FIG. 5.—Showing Action of Inlet Valve on Suction Stroke.
FIG. 6.—Piston Nearing End of Compression Stroke. Position Just Prior to Ignition.

When the piston has returned to its outermost point (or a little before, in actual practice), the highly compressed fuel is fired and the intense heat is turned loose upon the task of expanding the confined gases and hurling them against the piston, now just entering upon its third or real power stroke, illustrated at Fig. 7. The impetus received from this carries the engine through the return or discharge stroke (Fig. 8), during which the exhaust valve, 3, is opened by mechanical means. These four strokes or two revolutions of the crank shaft complete the cycle of the four-cycle engine.

21. **Two-Cycle and Four-Cycle Engines Compared.**—In the two-cycle engine all of these operations are accomplished with one revolution of the crank shaft or two strokes of the piston. Theoretically it has several important advantages over the four-cycle, and may in time become the more popular engine of the two. As it gets a power impulse with every revolution there is less tendency to speed variation and it does not require such heavy balance whéels to carry



7 8

FIG. 7.—Piston Descending on Power Stroke.
FIG. 8.—Depicting Action of Exhaust Valve on Scavenging Stroke.

it through the intervening periods. For the same reason the power is considerably increased for the weight of the engine. The valves are in part or wholly dispensed with and a long chapter of trouble from their fouling or warping with the heat is avoided. The two-cycle engine has fewer moving parts, less opportunity for wear and is easier to understand. Because of the greater frequency of explosions it is smoother running than a four-cycle engine having the same number of cylinders.

22. **Why the Four-Cycle Engine Is Preferred.**—In practice, however, it has not been found possible

to rid the combustion chamber of burned gases in the small part of a stroke the two-cycle engine devotes to that work; neither does it, in the hurried blending of operations, take in a proper supply of fuel and, though it takes up a charge twice as often, it does not make as good use of it or give out proportional results. So, while the two-cycle engine gives out more power for a given number of pounds of engine, the four-cycle delivers greater power from a certain quantity of fuel; and fuel, of course, represents a definite, continuous expense. The crank case, too, of the simpler two-cycle motors has to be gas tight and considerable difficulty obtains in keeping it tight after the bearings become worn around the shaft which extends through them. At the present stage of development the two-cycle engine has a great number of theoretical advantages, but the features of the four-cycle power plant are of greater importance in practical field work.

23. **Six- and Eight-cycle Engines.**—Six-cycle engines have been manufactured on a small scale, the two extra strokes being devoted to the discharge of all burnt gases and the admission of pure air. Even an eight-cycle engine was recently announced. Their advantages, however, are so questionable and their use so much of an experiment that at the present time they may be regarded as more of a curiosity than anything of practical importance.

24. **The Vital Parts.**—Every gasoline engine of whatever form, in order to convert the energy of combustion into working energy, must have a receptacle for the confinement and explosion of the gases; a means of introducing the fuel to its place in proper quantities; a system of firing the charge, and a movable plunger to receive the impulse and convert it into

mechanical motion. These may be considered the vital parts of the engine. Then there is the frame necessary for its support and for keeping the other parts together in their relative positions.

25. **Other Necessary Components.**—There are certain parts which do not enter directly into the operations of the cycle, that are none the less essential to continuous operation. A crank shaft is necessary to convert sliding into rotary motion and a belt pulley

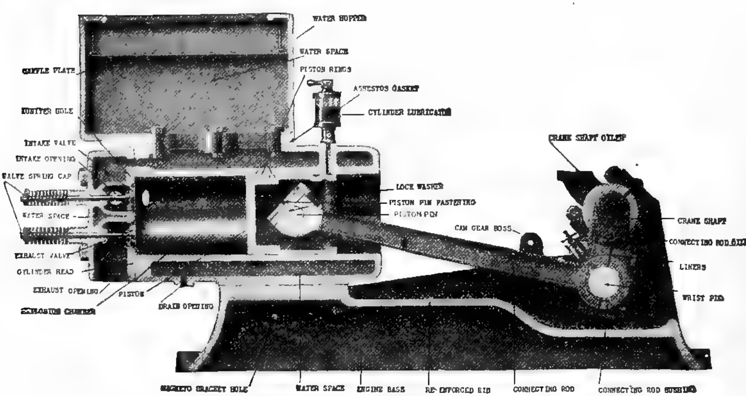


FIG. 9.—Sectional View of Reeves Horizontal Engine, Illustrating All Important Parts of Modern Gas Motor.

or some substitute is needed to transmit it. A connecting rod between piston and shaft is a necessity; also a piston pin; some form of governor to regulate the speed; valves to admit and retain the gases, and a timing mechanism to regulate the operation of the various parts in unison with each other.

26. **Conveniences Which Are Necessities.**—Some of the conveniences, too, are so essential to the continuous operation of the engine that they may almost be considered necessary, although they take no direct

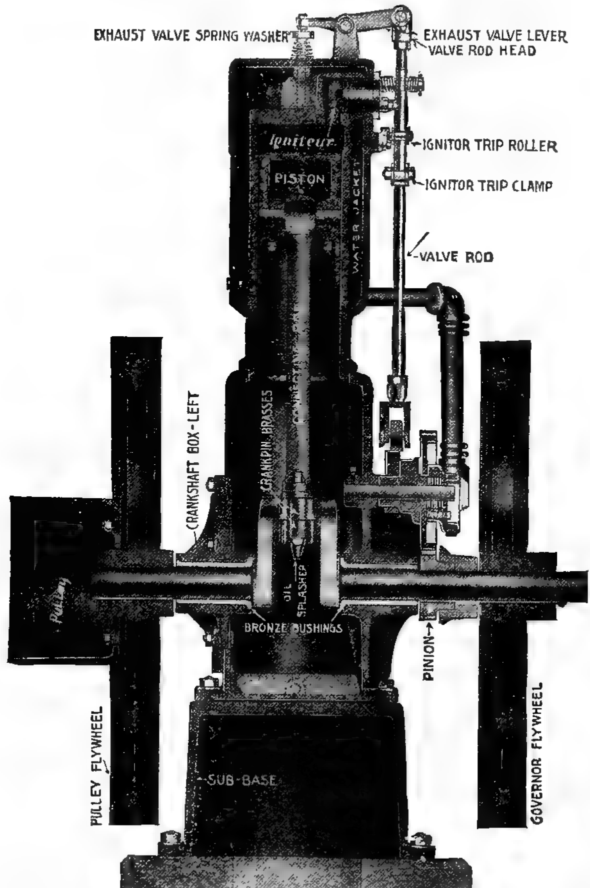


FIG. 10.—Sectional View of Vertical Engine, Showing Important Components.

part in the operations. Chief among these is a fuel tank, without which the time of the operator would be constantly taken up in introducing liquid to the intake system. Cooling provisions must be made un-

less one is willing to shut down frequently or else stand beside the engine with dipper and pail. Except for the piston lubricator, no other oiling provisions are necessary than occasional oil-holes over the bearings, but the life and efficiency of both engine and operator will be greatly extended by the use of lubricating cups. Other attachments or trimmings, which may be luxuries with some engines or in certain lines of work, become actual necessities under other circumstances.

27. **Other General Types.**—Besides the vertical and horizontal engines, there are several kinds made for special purposes which are so constant in some characteristics with all makers that they may be classed as distinct types; the marine engine, made without base and designed particularly to meet the requirements of the motor boat; the automobile engine, also lacking the solid base that characterizes the farm and factory engine and introducing the opposed cylinder principle in which two or four cylinders are arranged to counteract each other's vibration under the power impulse, and to give the crank shaft an impulse in the one direction, while the resistance of compression is being exercised from the opposite side. The motor-cycle engine might also be included as an extreme type of light and baseless engine, though the last word of all in point of lightness is spoken by the aviator's motor, some types of which have been created with a capacity of one horse-power per 3 pounds weight. With the possible exception of the automobile and motor-cycle engines, none of the above are entitled to a legitimate place upon the farm.

CHAPTER III.

THE COMBUSTION CHAMBER.

28. **Functions of the Cylinder.**—The primary mission of the engine cylinder is receptive rather than operative. It is the gun barrel into which the fuel is introduced and wherein the gases are expanded by the heat of combustion until they exert a tremendous energy in their struggle to occupy a much larger space than they did before the heating took place. This energy, hurled against a movable piston at one end and confined between rigid walls in all other directions, forces the sliding metal back with so much energy that the crank shaft to which it is attached at the outer end is carried past its center and far upon the return stroke against the burned-out gases which have as quickly lost most of their heat and power of resistance.

A second service of the cylinder is the confinement of the fuel gases at a point where they will be compacted by the up-stroke of the piston and in that compressed form fired by the spark.

29. **The Influence of the Cylinder Upon the Engine.**—The position of the cylinder determines whether the engine is to be horizontal or vertical in form and fixes in a great measure the power and special line of work to which it will be best adapted when finished.

In this chamber all operations which originate or represent force are transformed into power.

30. **The Best Material.**—The best gray cast iron is now favored for the cylinder. This is an iron which contains sufficient graphitic carbon, that is uniform of texture, and which is reasonably free from phosphorus and sulphur. Patches of light and dark gray are serious defects, as they indicate a difference in texture which may result in uneven expansion under high temperatures. An engine cylinder must stand a temperature which varies from about normal to very little below the melting point of iron and, in order to expand evenly, must be of absolutely the same material in all its parts. Cheap iron may look as well as any other, but it will contain weak places which the extremes of heat and pressure developed in the cylinder are sure to find.

31. **The Work of the Foundry.**—Engine cylinders must be well cast. Dirt pockets or blow-holes are not permissible. In order to insure prompt cooling the walls have to be as thin as the stress upon them will permit, and such thin castings have to be poured much hotter than heavier pieces in order to prevent the smaller stream of metal from getting too sluggish to fill out the corners of the mould well. At this stage of engine building the little defects must be particularly guarded against, the air bubble, the bit of unfusible foreign matter, the sand scale, the unfilled corner. Even with the best of foundry work, a good many cylinders that come from the mould smooth and seemingly perfect must later be rejected because of defects that are disclosed by the lathe. The care required at this stage, and the extra cost in production it sometimes occasions, should not be lost sight of by the man who wants to buy a **good** engine, but who is inclined to be unduly influenced by a low price.

32. **Boring the Cylinder.**—Even greater care, if

anything, is needed in the boring and finishing of the casting and a good many inferior engines originate through a cheapening of this process, either to meet the demand for a low-priced article or through the practice which some amateur machinists have of buying the castings and finishing them up themselves.

The casting to be bored must have absolutely rigid support; there must be no spring. The bore must also be a true circle and perfectly centered so that all of the wall surface will be of uniform thickness. The first cut is made quite heavy; then in the best made engine cylinders the casting is removed from the lathe and allowed to "rest" for from 30 to 60 days; this to allow all molecular strains and stresses to "season out." Then a second cut is made, very much lighter than the first and intended mainly to remove the drill marks of the coarser tool. Some makers follow this by a third cut, which is exceedingly fine. The final cut is followed in most of the best engines with a fine emery wheel revolving at a very high speed and removing the last one-thousandth of an inch of cut with almost mathematical precision. This accuracy must obtain the full length of the cylinder and the bore must not vary in size or from its circular form. Because of the vibration set up in the grinding machine by the high speed and the solidity with which the work must be held against the tool so that there is no springing away from any hard spot in the metal, it is very necessary that the machine frame be rigid far in excess of the requirements for such seemingly light work.

A few manufacturers argue against the grinding method, partly on account of its cost and the heavy machinery required, and partly because of the possibility that particles of emery and abrading powder

may remain in the cylinder walls to score them or the piston when in use. Most of the best grade engine cylinders, though, are finished in this manner. Whatever process is used, the walls should be left entirely free of tool or chatter marks, and with a mirror surface. Fig. 11 illustrates a smooth, absolutely straight wall (indicated at **c**), as it should be. At **a** and **b** are shown respectively high and low spots caused by the springing of the thin cylinder walls as the boring tool

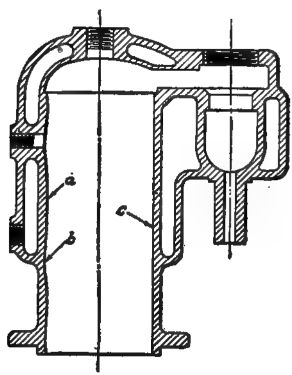


FIG. 11.—Illustrating Defects Liable In Boring Cylinder. Compare Defective Spots Shown at a and b With Perfect Wall at c.

passed over hard and soft places in the metal. Perfect compression can never be obtained in a cylinder like that.

A ground cylinder, if properly finished, gives as nearly perfect results as we can hope to attain and at the same time the small sharp particles of the vitrified grinding wheel do their work by means of so many and such rapidly moving points that the walls are left smooth as a mirror and absolutely true, since there is practically no pressure put upon them.

Lapping and all forms of smoothing out with powdered glass or other abrasing material, while fairly effective if well done, require very careful cleaning, as any of the cutting material left in the cylinder would be likely to continue its work of scoring upon both cylinder and piston.

33. **Severe Duty as Combustion Chamber.**—Of its several functions, that of combustion chamber is more exacting than any other to which the cylinder is subject on account of both the excessive temperature and the pressure. While neither of these can be very accurately determined, it is generally considered that an initial pressure of around 350 pounds per square inch gives the most economical results, while it is probable that at the moment of discharge the temperature developed inside the cylinder varies between 2,000 and 3,000 degrees Fahrenheit, depending a great deal upon compression, hotness of spark, correctness of the mixture, etc.

34. **What Compression Is.**—A bit of gun cotton, fluffed into a light mass, may be ignited without danger on the palm of the hand. The same mass, confined in the barrel of a gun, would hurl a charge out through the muzzle with considerable force. In the one case the expansive gases are free to escape without hindrance. In the other the force is confined. The amount of gas is the same in both cases but the expansion is more violent in its results because of the momentary compression. Let us now ram into the gun barrel all the gun cotton that can be crowded into the same space under pressure; probably several times as much as was in the first charge. When the gun is fired we have several times the quantity of gas expanding suddenly in the same fixed space and the firing charge is either hurled out with

tremendous energy or else the barrel itself must burst.

35. Compression in the Gasoline Engine.—When the piston of the gasoline engine has reached its highest or inner point there is a short air space between it and the end of the cylinder, usually about one-fifth of the entire cylinder volume. If we now opened the inlet valve and allowed the fuel vapor to enter, it would fill this space until the internal pressure equaled that of the air on the outside, or about 14.7 lbs. to the square inch; then no more fuel would enter. By firing this charge, that is, raising the temperature to the combustion point, the gas would be expanded until it occupied several times its original volume and the pressure or forward thrust against the piston would be, we will say, something like 90 lbs. per square inch of surface. This, working against the normal atmospheric pressure of 14.7 lbs., would leave us 75 lbs. of active working energy.

Before firing the charge let us now, with the intake valve still open, advance the piston to the outer end of its stroke and so increase to five times its first dimensions the receptacle for fuel gas. This greater area, like the other, fills to the point of atmospheric pressure; then we turn the piston back to the end of its inner stroke.

36. How the Charge Is Compressed.—As soon as the gas fills the cylinder and is pressed upon by the returning piston it closes the intake valve. It cannot escape in that way. The rings prevent its slipping out between the cylinder walls and the piston. It is simply forced or pressed together as the gun cotton was pressed, until, when the piston is at the end of its inner stroke, the gas has been compacted into about one-fifth of its normal volume and consequently

is struggling to escape with force five times greater than atmospheric pressure or nearly 80 pounds per square inch. We now fire the charge and the expanding gases call for nearly five times greater space than before, bringing the theoretical working pressure hurled against each square inch of the piston head up to over 400 pounds. Deducting the original atmospheric pressure from this, we have a working energy of about 400 pounds per square inch of piston head surface.

37. **Compression Limits.**—If the working energy of the fuel may be rendered so much more available by a moderate compression it would seem that we might increase our power almost indefinitely by diminishing the clearance volume of the cylinder, but in practice it is found that this can be done only within moderate limits. After a certain amount of compression has been done the resistance of the gas becomes so great that it uses up as much power in compressing it as we gain by the higher compressed charge. Of still greater importance is the fact that the compression of gas introduces considerable heat and the moment we carry this process beyond a certain point so much heat is generated that the fuel is fired before the piston reaches its proper position. In other words, if we carry the compression of gasoline much beyond 100 pounds, the charge is liable to be fired against the ascending piston by the developed heat, thus reducing instead of increasing the working energy of the engine by hurling one impulse against another.

38. **Where Higher Compression Is Useful.**—Where alcohol is used as a fuel it is found that the compression may be run much higher without danger of pre-ignition; in fact, an alcohol engine to work efficiently

requires a compression of something like 140 lbs. per square inch.

It has been suggested, too, and has been a dream with gasoline engine men, that some means of shifting adjustment might be introduced whereby an ignition temperature would just be generated at the point where the charge ought to be fired. This would do away with the necessity of batteries, magneto, or any other firing device. Promising experiments have been conducted along these lines, but as yet the promises have only been realized in part.

39. **Compression Gains and Losses.**—Since internal combustion engines are heat engines, and the heat we are obliged to dissipate in order to protect the cylinder and its associates is wasted energy, it follows that the smaller the surface we are forced to cool without sacrifice of temperature the more we gain in efficiency. This is another reason why compression adds to the efficiency of the engine, the real combustion chamber being practically confined to that small portion of the cylinder into which the fuel is compressed at the moment the charge is fired.

"It has been shown that an ideal efficiency of 33 per cent. for 38 lbs. compression will increase to 40 per cent. for 66 lbs., and 43 per cent. for 88 lbs. compression. On the other hand, greater compression means greater explosive pressure and greater strain on the engine structure, which will probably retain, in future practice, the compression between the limits of 40 and 80 lbs.

"In experiments made by Dugald Clerk in England, with a combustion chamber equal to 0.6 of the space swept by the piston, with a compression of 38 lbs., the consumption of gas was 24 cubic feet per indicated horse-power per hour. With 0.4 compression

space and 61 lbs. compression, the consumption of gas was 20 cubic feet per indicated horse-power per hour; and with 0.34 compression space and 87 lbs. compression, the consumption of gas fell to 14.8 cubic feet per indicated horse-power per hour—the actual efficiencies being respectively 17, 21 and 25 per cent." Gardner D. Hiscox, in "Gas, Gasoline and Oil Engines."

40. **Clearance.**—Between the top of the piston at the instant of its extreme inner stroke and the closed end of the cylinder is a space into which the charge is compressed. This is the "clearance" of the engine and it usually amounts to about twenty or twenty-five per cent. of the combustion chamber, the exact percentage of course determining the compression of the engine, provided rings and valves are doing their work properly.

41. **Faulty Compression.**—While a gasoline engine can be operated without compression, it is always done to the tune of extravagantly wasted fuel and without the satisfaction of accomplishment. Such an engine has very little power, so it is evident that any faults of compression are eliminated only at the expense of both the fuel tank and the belt wheel. Faulty compression is generally due to a worn or badly seating valve or piston ring, or to some leak in cylinder walls or piston. Blow holes in the castings will cause it; so will rings that are rough upon the edges or either too narrow or too wide for the grooves they occupy. If the ring is too wide the edges bind in the groove and keep it from opening freely against the cylinder walls; if too narrow, so that there is a little end play in the groove, there is an instant of time at the dead-center of the inner stroke when the ring pressure shifts from one side to the other of the groove, at the in-

stant that the piston reverses its motion. During this period the ring touches neither side and permits a brief but many times repeated leakage of highly compressed gas or of the explosive force which has just been delivered against the piston. Dirty, gummy rings cause similar trouble. A ring must work absolutely free, but without any reciprocating or end motion, in order to do its work properly.

42. **Testing Compression.**—The compression of a five H. P. engine should as a rule be too great to permit of the wheel being turned over by hand without opening the relief cock in the cylinder, while even a one and two horse engine should put up stiff opposition. By holding the piston of the engine at the end of the compression stroke for a few moments the amount of compression leakage at the most critical point may be determined but it must be remembered that this test alone does not determine the operating compression of the engine, as many leaks which do not appear at this point may cause trouble at some other place or while the parts are in motion.

A hissing sound is indication of a leak somewhere and, by listening at the inner and outer end, the leak can frequently be located at once. If it comes from the lower or open end of the cylinder the fault is somewhere about the piston, its rings or the castings; or perhaps a worn or scored cylinder wall, or one that is not true. If the sound seems to come from the other end of the cylinder, test the exhaust valve and see that it seats properly; also, that the stem works easily in the guide. Make this test while the engine is at running heat, then try the intake valve. A little soapy water may sometimes help in determining the leak, the escaping gas creating bubbles. Sometimes

a broken thread on the spark plug will cause a leak around its base.

If the cylinder and head are cast in two separate pieces the joint and packing between them should be carefully examined. In a two-cycle engine worn crank shaft bearings are as troublesome avenues of leakage as the piston rings in a four-cycle engine. Where the leak is external it should not be difficult to locate, but in case of an internal leak into an enclosed crank case, a water jacket, a muffler or some other hidden part of the engine, it sometimes becomes quite a puzzling problem, but the search should be persisted in until the trouble is found, as otherwise serious damage may result.

Leaks in multi-cylinder engines are more difficult to locate than in a single cylinder, the compression strokes frequently overlapping or blending together. This difficulty may be overcome by removing the spark plugs of all but one cylinder; then turn the wheel over and note the compression in that. If satisfactory, remove the remaining plug and place it in one of the other cylinders, which may then be tested, until all are tried. The source of leak once located, the remedy is self-evident.

43. **Decreasing the Clearance.**—The crank shaft bearings always wear away most rapidly on the side opposite the cylinder and through wear the piston may be drawn farther out and so increase the clearance or compression space and weaken the pressure. Metal disks have sometimes been bolted to the end of the piston in order to overcome this but the remedy is objectionable, as are all other remedies which introduce bolts into the combustion chamber. Another way is to lengthen the connecting rod, but it would seem

that the simplest and cheapest method would be to restore the worn bearings to the condition thought necessary by the designer. Changes of this sort should be made with a good deal of caution by the amateur engine operator, but when one is certain the compres-

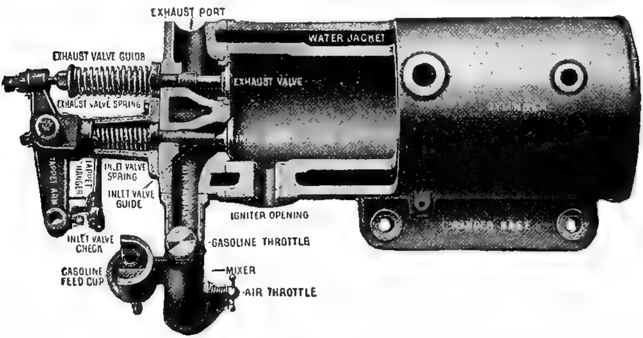


FIG. 12.—Sectional View of I. H. C. Engine Cylinder, Showing Water Jacket and Valve System.

sion is really defective one should not hesitate to adopt any necessary remedy.

44. Increasing Power by Decreasing Clearance.—While less clearance means greater compression and more power within certain limits, there will come a time when the extra power generated will be more than absorbed in making the extra compression, even if the fuel used does not limit the point to which the process may be carried. Up to this limit, however, or to the point where the increased temperature causes pre-ignition, this resistance against the ascent of the piston, or negative stroke, as it is termed, is not without its use. Were the power stroke of the engine allowed to exert its force entirely against the solid mechanism, the strain and jerky effect would be far more pronounced than it is when finally caught in

part against this elastic cushion of compressed gas.

45. Lubricating the Cylinder.—The requirements which gas engine cylinder oil must meet are so different from those of the steam engine cylinder that to use the very best oil suitable for the latter might be worse for a gas engine than to use none at all. In the first place, the temperature of the combustion chamber is so great that ordinary oil is burned up at once, before it has a chance to do its work as a lubricant. Then the combustion leaves a residue of carbon and dirt which in themselves do harm. Steam engine cylinder oil **must** not be used in the gasoline engine cylinder, even for a short run. To this rule **there is positively no exception**; at least not for the novice. The subject of proper and improper oil is fully discussed in another chapter. A word here is sufficient in explanation of how the oil should be introduced.

All parts of the cylinder requiring oil are usually reached through the lubricator which oils the piston and its rings, the oil dropping or being forced through its channel upon the piston rings which scrape and spread it over the surrounding surface of the cylinder against which they press. No other part of the surface needs oil.

The system of oiling the cylinder through the fuel mixture, which is becoming more and more popular, is fully described under its proper head.

46. Carbonizing, Its Cause and Effects.—The best of oil, under the test which is placed upon it by gasoline engine temperatures, is very quickly consumed, though not, in the case of good oil, until it has had time to accomplish its mission. The best of oil contains some carbon, which is released by the process of combustion and spreads itself over all sur-

faces to which it has access, the piston head, the rings, the cylinder walls and combustion chamber, the valves and the muffler. A glance into the muffler of an engine which has been long in operation will show the extent and nature of this deposit. Inside the cylinder, however, it is subject to the alternate influence of moisture and baking heat, and eventually a hard, slaty shell may be formed in some parts while in others the deposit will be more of a tarry, sticky nature. In either of these forms the free action of the valves or the rings is likely to be interfered with. This alone occasions many gas and pressure leaks.

Scaly projections of this coating are liable to become in part detached and to so stand out that they receive the entire heat impulse without being in contact with any cooling influence. In this condition they quickly become heated to a dull red and, after the fuel charge is inhaled by the down stroke of the piston, as compression begins and the temperature increases on the upstroke, these living coals may fire the charge against the ascending piston, not only wasting the power impulse, but extending it directly against the proper working of the engine. This is one of the most common causes of pre-ignition.

This heavy scale of hard carbon, too, may interfere seriously with the cooling of the cylinder walls and cause heating of piston or cylinder. Carbon in the cylinder is one of the most frequent troubles with which the gasoline engine man has to contend.

The lubricating oil is not the only source of these cylinder deposits. An excess of oil may cause them, or too much gasoline. All the gasoline vapor which fails to find sufficient oxygen from the air supply to produce carbonic acid, carbonic oxide and water will deposit free carbon, providing the heat is great enough

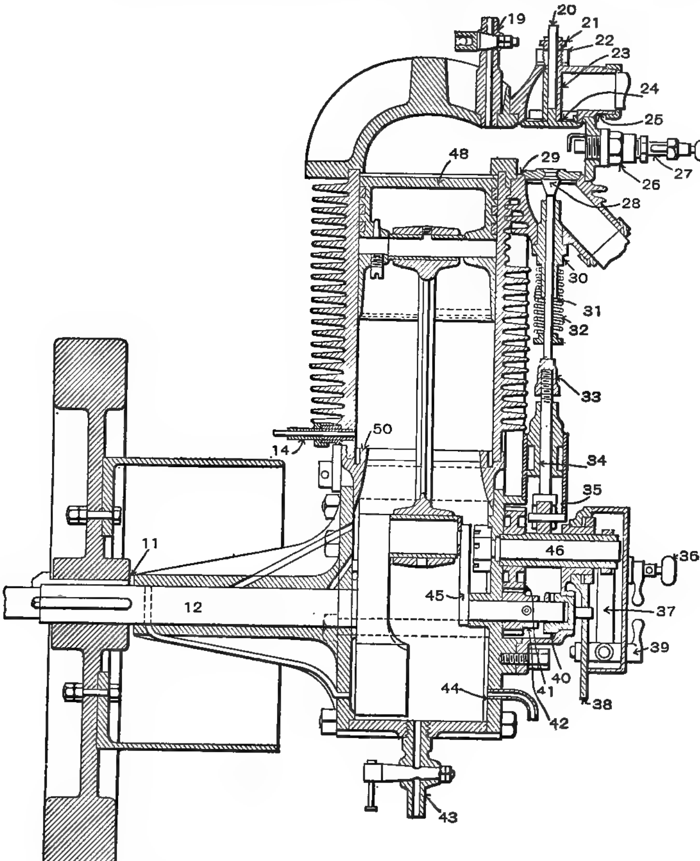


FIG. 13.—Sectional View of Air Cooled Motor. Figures Denote Following Parts: 12—Crankshaft. 14—Oil Pipe. 19—Petcock for Compression Release. 20—Valve Spring Key. 21—Valve Washer. 22—Inlet Valve Spring. 23—Inlet Valve Guide. 24—Intake Valve. 25—Valve Cage. 26—Sparkplug. 27—Sparkplug Porcelain. 28—Exhaust Valve. 29—Exhaust Valve Seat. 30—Exhaust Valve Guide. 31—Exhaust Valve Stem. 32—Exhaust Spring. 34—Exhaust Operating Rod. 35—Cam Roller. 36—Timer Cover Screw. 37—Contact Spring. 38—Timer Advance Lever. 41—Timing Pinion. 42—Cam Gear. 43—Drain Cock. 44—Pipe Regulating Oil Level. 45—Gear Operating Shaft. 46—Camshaft for Exhaust. 48—Piston. 50—Oil Groove.

to break up the gasoline formation. To this silicon and various impurities of the air are added.

47. **Symptoms of Carbon Deposit.**—Pre-ignition is one symptom of carbon. It is announced by the knocking of the engine the same as when the spark is advanced too much. Back-firing is frequently caused by carbon holding the valve from closing. Misfiring may be occasioned by carbon short-circuiting spark plugs or by the gap between the points being entirely closed. Usually only a part of the current is short-circuited; then the spark is weak and the ignition irregular. One of the most characteristic symptoms of carbon deposit is the presence of plenty of power at high speeds but little when speed is reduced and load thrown on. This is due to the fact that the carbon causes pre-ignition when the speed is slow while at high speed an advance of the firing instant is not great enough to catch the rapidly moving piston on the up-stroke with any retarding force.

48. **Cleaning the Cylinder.**—At least once or twice a year the piston should be taken from the cylinder and all carbon deposits thoroughly removed. If the head is removable it is a comparatively easy matter to thoroughly clean all parts. Kerosene is one of the best liquid cleansers. Do not use gasoline, as it destroys the smooth mirror glaze with which the iron walls have become polished and leaves the original porous surface of new iron. Do nothing to destroy or break up this glaze. Besides, gasoline is not as good a solvent of carbon as kerosene, which is less harsh in action.

When the deposits are very hard, scraping may have to be resorted to. This should be done thoroughly but with care not to injure the surface of the cylinder or to scratch the walls. Particularly should

care be taken to remove all loosened scales and particles, if necessary using kerosene in a closed end cylinder. A cylinder should seldom be opened up. When it is done, let the cleaning be thorough. Note specially the nature of the deposits and so form an estimate of the brand of lubricant in use.

49. **Removing the Cylinder.**—So many different patterns exist, only the most general rules can be given for this. All pipes should first be disconnected from the cylinder casting, water pipe, exhaust pipe, etc., then the bolts holding it to the crank-case may be loosened and cylinder removed; or, it may be necessary to loosen and remove piston. In either case great care must be taken not to injure the piston or rings. If the head is removable place that and the nuts which are taken off with it in a bath of kerosene while scraping and cleaning the cylinder walls. Copper, soft steel or bronze tools should be used for scraping. Never insert chisel or other tool between head and cylinder to pry the head loose.

50. **Reassembling the Engine.**—In rebolting the closed end cylinder to its base, or the removable head to the cylinder care should always be taken to avoid throwing excessive strain on any one bolt alone. Tighten all up together, or nearly so, and avoid danger of a cracked casting.

To return the piston and rings to the cylinder easily, compress each ring tightly to its groove and fasten it there by wrapping each with a separate coil of soft copper wire. Insert piston head in cylinder and advance carefully. As each coil of wire is reached it is forced ahead of the end of cylinder, toward the lower end of piston after the ring has been entered into place enough to be secured. Finally the wires will all be slipped down upon the connecting rod, from

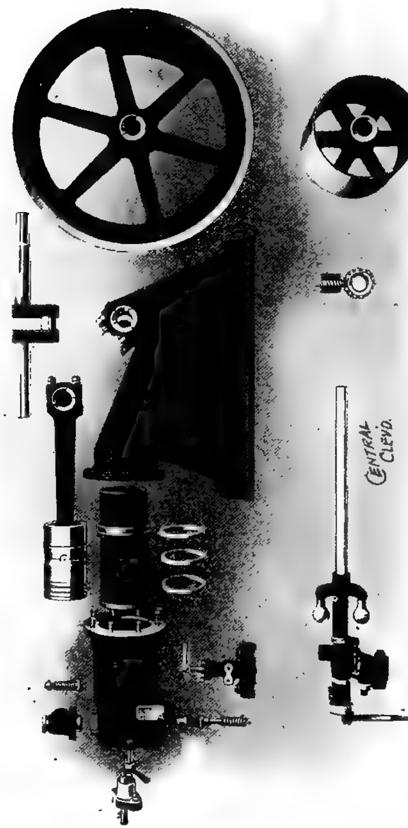


FIG. 14—Vital Parts of a Jacobson Horizontal Gas Engine.

which they may be readily removed. This saves much trouble in compressing and holding in place several unruly and delicate rings.

51. **Packing the Cylinder Head.**—Blown-out or defective cylinder packing has been the cause of as much profanity among gas engine users probably as any one source of trouble, not even barring the ignition system. The avoidance of this trouble should begin at the factory, in the construction of the engine; if not there, then in its selection. See that all packed joints are held with studs and not with cap screws; and that the studs are ample in size. A little carelessness and an ordinary monkey wrench may twist off a ½-inch stud quite easily, although that is a size made use of by a good many builders of small engines. A ¾-inch stud is quite likely to take care of itself.

52. **Material to Employ.**—All rubber or other packing injured by heat is barred from use around the combustion end of the gasoline engine cylinder. Ordinary asbestos mill board is as good as anything if applied right, and is much cheaper than the wire wove and other special brands. One sheet of 1/32-in. mill board is usually enough and if a thicker packing is needed, two sheets of this thickness are better than one of a heavier grade. Copper-asbestos packings, in which a piece of asbestos board is sandwiched between two layers of copper sheeting, are the best.

As soon as the head is removed from the cylinder the old packing should be scraped and cleaned off thoroughly before it has time to dry. The surface must be perfectly smooth and level if a tight joint is expected.

Do not mark out the new packing by hammering the sheet material lightly against the face of the cyl-

inder head. A few such treatments are almost certain to send the head back to the lathe for refacing. By laying the sheet upon the faced side of the head and rubbing along all edges with the finger a sufficiently distinct mark will be made; then lay sheet upon a clean board and cut out with a sharp knife. Dip the sheet in boiled linseed oil but do not allow it to soak long or the asbestos fibres will have a tendency to separate. If one side is coated with a good quality of flake plumbago it will detach readily from head when next removed and will be fit to use again. In case a packing is specially difficult to hold, shellac is sometimes added. Allow no fragments or edges of packing to project into the combustion chamber or they may heat and cause pre-ignition and be careful that no ragged edges project into water ports or gas openings.

53. **Cleaning Cylinder Without Removing Head.**— If not convenient to shut down for a complete cleaning of the cylinder a very effective temporary method which has been known to answer for some time is to work equal parts of alcohol and carbon disulphide into the cylinder through the lubricator. This acts quicker without oil but enough of the latter must be included to keep the cylinder from cutting while the other is being applied.

By pouring alcohol and kerosene in equal quantities into the top of the cylinder slowly when shutting down at night the carbon may also be loosened; then do not be deceived into thinking the oil bad the next day on account of the dense smoke which rolls out of the muffler.

Where scraping must be resorted to it may be done through any small opening in the top of the cylinder by use of a mirror to reflect the light, or by introducing a small incandescent bulb. The scraping can

then be done by means of soft steel wires the ends of which have been fashioned into sharp scrapers or hoes bent at different angles. Never use hard, brittle material for this purpose, or any metal that might fracture and leave fragments in the cylinder.

CHAPTER IV.

THE PISTON AND AUXILIARY PARTS.

54. **The Piston's Several Functions.**—Upon the smooth fit of the piston and its rings depend the four important functions of drawing in the fuel vapor, compressing the charge, receiving the impulse and converting it into mechanical action, and scavenging out the cylinder in advance of the next cycle. More care is required to secure a perfect fit for the piston in the cylinder and the rings in their grooves and against the cylinder walls than in any other part of the engine, for, without the highest degree of efficiency at this point, the full power of the most carefully constructed engine can never be developed. Use will frequently improve a set of poorly fitting rings but will seldom if ever make them as efficient as they would have been if properly fitted in the first place.

55. **Construction of Piston.**—The piston may be described as a short cylinder closed at one end by a flat head, open at the other and attached to the connecting rod at the center by a pivot or piston-pin. Between the head and the piston-pin a number of grooves are cut around the outside of the piston for the reception of the rings. These vary in number with different engine builders, three or four being usually considered enough for small and medium size engines, with possibly one between the piston-pin and the open end to assist in the lubrication process.

56. **The Best Material.**—Pistons should be made

from a close grained gray cast iron, of a texture similar to that used in the cylinders in which they work; then the expansion from heat will be more nearly alike in each. They must contain no sand holes, blow holes or other serious foundry imperfections, else there is likely to develop a troublesome leak which may be hard to locate.

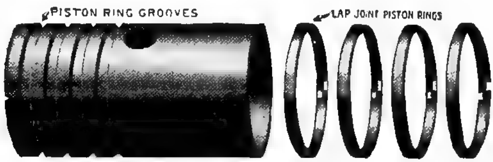


FIG. 15.—Piston of I. H. C. Engine and Rings.

57. **Design and Workmanship.**—Gasoline engine pistons must be longer than the pistons of steam engines because the piston rods are not steadied by guides but are united to the crank shaft through a single connecting rod. This, without the greater length, would give a tendency to tilt or rock. From one to one-and-a-half times the diameter is the length most favored in the United States, though in Europe much longer pistons are used, and more rings. Flat surface piston heads are generally considered best because they cool more evenly than a curved surface. Deflecting lips and all projections are defects, as they are apt to over-heat, often to the point of causing pre-ignition. Built-up pistons are usually objectionable, as the bolt heads retain too much heat. The one-piece piston is best.

58. **Piston Rings; Their Purpose.**—It would not be possible to fit a solid block of iron so closely within the walls of the cylinder that no gas could escape between them and at the same time keep it loose enough

to work easily back and forth at high speed under a great variation of temperature. This is not attempted. Instead, the diameter of the finished piston is made slightly less than the bore of the cylinder and the

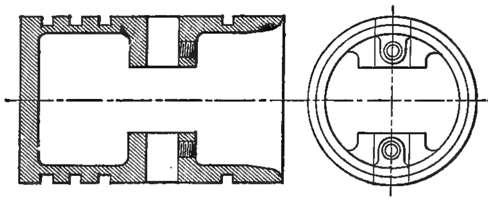
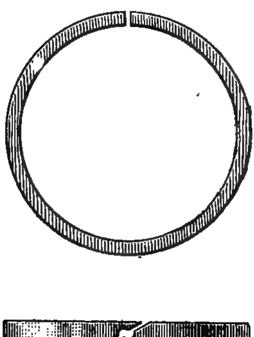


FIG. 16.—Longitudinal and Cross Section of Typical Piston.

escape of gases past it is prevented by introducing expansive rings into grooves cut in the surface of the piston. The rings should fit closely but smoothly in their grooves and, by their tendency to expand, should



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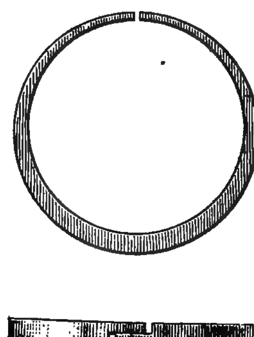

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FIG. 17.—Concentric Ring With Diagonal Cut Joint.
FIG. 18.—Eccentric Ring With Stepped or Lapped Joint.

press lightly against the cylinder walls at all points. At the same time their elasticity reduces the friction to the minimum.

59. **Construction of Rings.**—The ideas of different engine builders vary greatly as to the best type of ring in width, thickness and style. Some favor the concentric (Fig. 17) and others the eccentric type, shown in Fig. 18. The matter of joints, too, is one of disagreement, the diagonal and stepped joint each having its adherents. Good rings, as well as poor ones, are made after all of these ideas, and it is for the engine owner to concern himself with results only, letting the manufacturer take care of his own means of obtaining them.

60. **The Best Material.**—An engine ring has to be sufficiently elastic to admit of spreading over the end of the piston into the groove without breaking. This requires a degree of toughness. Once in its place, however, it must spring back to its original form; hence it must be hard enough to retain its tensile strength. The happy medium between the two extremes is rather difficult to find, because iron varies so much in its grading. A ring that is tough enough to open without breaking is likely to be too soft to return to its original shape. One having spring enough to resume its circular form may easily break in spreading.

61. **Making the Ring.**—The best rings are machine moulded from brass or iron patterns. They are then more uniform. These castings are tube-shape and the rings are cut in a lathe from this, a trifle wider than the groove they are to fill. They are then faced to a standard width from both sides and a small piece cut either diagonally across the metal or in the form of a stepped joint. It is probable that there is very little difference in the merits of the two when properly fitted. In the case of eccentric rings the cut is made in the thin side.

62. Truing the Ring.—In some cheap engines the rings, after being cut or split, are merely forced together. Such a ring is not a true circle but assumes a slightly oval shape, hardly noticeable to the eye. It bears against the cylinder walls at two points only and wears them oval, while the rest of the way around there is a leak because it does not touch. The split ring ought to be clamped together in a lathe, returned or ground to a true circle, and then finished up before it is sprung into place upon the piston. It will then seat itself evenly in the groove and give a uniform outward pressure clear around against the cylinder walls. Even then, if there are hard and soft spots in the metal, there will be high and low places in the ring, due to uneven tension, so it is specially necessary that metal for piston rings be of uniform texture. Some manufacturers give their rings a specially desirable surface by a light lapping with powdered glass or grinding with a hard wheel. The abrasive must be carefully cleaned off after the lapping is completed or it will adhere to the surface and tend to cut the walls of the cylinder to some extent.

63. Piston and Ring Defects and Their Remedy.—Two special remedies may be relied upon to prevent nearly every defect of piston and rings; cleanliness and lubrication. Unlike other machine bearings, the temperature is so high that ordinary lubricating oil, if used on the piston, is carbonized before its mission is accomplished, while every flash of the fuel in the presence of poor oil deposits a new layer of carbon, gum and trouble-breeding residue. The best of gasoline engine cylinder oil must be used at this point or there is sure to be trouble. All modern gasoline engines have some provision (see Fig. 19) for feeding the oil in a small but continuous supply against the piston

and the rings and then spreading it over the cylinder walls. Even a very brief failure of the supply, on account of a clogged oil tube or empty cup, may set the piston or cylinder to cutting and render reboring necessary; or disaster may come to the piston rings instead; as the oil is very quickly burned up, leaving the surface hot and dry after each flash. Since the engine may continue to work for some time without complaint while it is being ruined, this point, of all others, should be watched most closely.

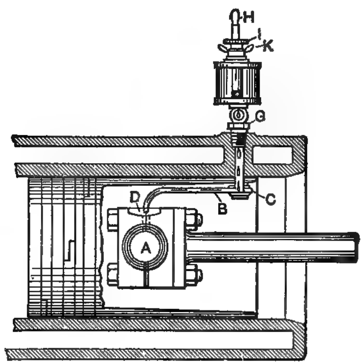


FIG. 19.—Piston Pin Oil Feed.

64. The Dirt Menace.—Cleanliness depends a great deal upon the quality of the lubricating oil used, but, even with the best of oil, the rings will become so coated in time with sticky or baked residue that they no longer close or expand freely in the groove; then compression will be incomplete and much of the power impulse will blow past the rings and piston into the crank case.

65. Cleaning Piston and Rings.—At least twice a year the piston and rings should be inspected and thoroughly cleaned by scraping, after the deposit has

been softened with kerosene. Gasoline, though sometimes used, is too powerful a dissolvent, for it removes the minute particles which have lodged in the surface grain of the metal and so destroys the mirror or glaze finish which use puts on the rings and cylinder and which renders an absolutely new motor less satisfactory at this point than one that has seen moderate use. This high glaze surface, once acquired, should neither be removed by chemicals nor severe scraping.

66. **Removing the Rings.**—It is a mistake for a novice to remove the rings from the cylinder every time the piston is cleaned, although some engine textbooks freely advocate that. A well tempered ring is a brittle affair and it requires more springing of the metal to remove one than to replace it; hence it is very liable to break in the hands of the inexperienced. Occasionally though it will be necessary to remove them in order to correct a roughened edge; then each ring should always be returned to its own groove. The best of machine parts develop some individual characteristic in use and it is more than likely that each ring will fit the groove in which it has been run better than any other.

67. **Replacing the Rings.**—Rings are not difficult to replace if three or four thin, narrow metal strips are used for slides and expanders until the ring is slipped directly over its own groove; then the strips may be pulled out. Rings should be so turned that joints in two successive rings do not come opposite each other and, if either edge of a ring presses more firmly against the cylinder than the other, let it be the one turned toward the combustion end.

68. **The Piston Pin.**—The piston or gudgeon pin should be made of high grade case hardened steel and

must be heavy enough to stand the jerking thrust of the full load delivered against it at every power impulse. As this sometimes reaches a maximum pressure of 450 pounds per square inch of piston face it is evident that a 4-inch cylinder, with a piston area

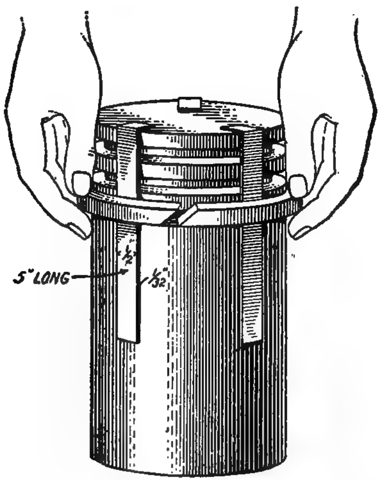


FIG. 20.—Simple Device for Removing and Replacing Rings.

of over 12.5 inches, might deliver sudden strains of about three tons upon the piston-pin. With the factor of safety figured in, the tensile strength of steel is about 2,500 pounds per square inch of projected surface, and the piston-pin of a four-inch bore engine, with something like a two-inch bearing, should be not far from one inch in diameter, which is about the size used in good engine practice. Even the cheap engines are usually provided with good material at this point, as the difference in cost of so small a part would be insignificant, while the certainty of at least a hole punched through the piston head in case of a broken

pin would be almost absolute. In the best engines the pin is ground to fit the piston bosses and is sometimes forced into place under pressure.

69. The Connecting Rod.—All of the power developed by the engine is delivered through the connecting rod and the full strength of the engine is consequently needed here. In the heavy, long-stroke

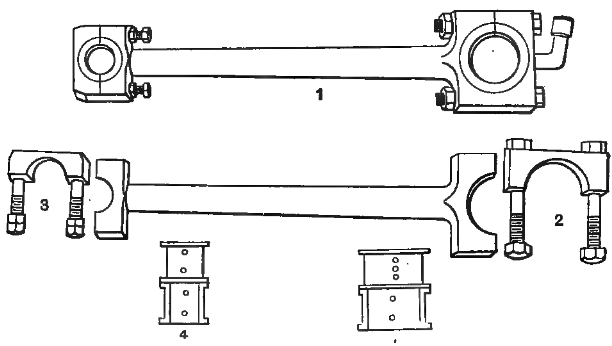


FIG. 21.—Marine Type of Bushed Connecting Rod.

engines the distance between bearings is relatively great and the rod must be heavier in proportion. On the other hand, a short rod tends to cramp the piston in the cylinder and increases the friction by side-thrust. Some engine builders favor drop forged steel; others use malleable iron, semi-steel or bronze I-beam type castings. There is considerable difference of opinion, too, about the bearings, especially for the piston-pin. Some still prefer the two-piece box, adjustable for wear, and secured by a bolt at each side (see Fig. 21); others adjust with a wedge, held in place by a single bolt, which also holds the box. A few have discarded all attempts at wear adjustment at the piston end further than to furnish a removable

bushing which can be replaced when worn out; this to avoid the danger from accident caused by bolts and wedges working loose. All makers provide adjustable bearings at the crank shaft, though not all use the same material. Phosphor bronze has the advantage of being unwearable and the drawback of cutting the shaft very rapidly if lubrication is neglected. Babbitt is too soft to be durable, but for that very reason is less a menace to the shaft, and the material is cheaper to replace.

70. **Crank Shaft and Connecting Rod Lubrication.**—The engine designer usually provides for the oiling of the piston-pin from the same cup that oils the cylinder and piston, so the operator has little more to do with this than to keep the lubricator filled. The crank shaft may be oiled by means of any ordinary lubricating device; or the splash system may be adopted where an enclosed crank case is used. Enough oil is poured into the case to reach the revolving shaft nicely at its lowest dip and is thrown or splashed over the bearings. This is a very sure and efficient system so long as the oil supply is kept at the proper level in the case and is not permitted to go too long without renewing. The system requires the occasional but not the frequent attention of the operator; in fact, there is no system of oiling yet discovered that will do its work unless a supply of oil is furnished by the watchful operator. The method that has to be attended to once or twice a day however is less likely to be forgotten than one that is self regulating for days or weeks.

Sometimes a wire ring or chain is suspended loosely upon the shaft and, as this slowly works its way around under the constant vibration, it carries up with it a quantity of oil continually (see Fig. 27). In

open end engines without a crank case oil cups or some similar devices have to be used.

71. **Repairs and Care.**—Considering the excessive strain placed upon its parts the piston and correlated parts seem wonderfully free from accident or from the necessity of repairs that an amateur can make. Occasionally the bearings need adjusting; the lubricating system always merits watchfulness; then an occasional clean-up when the carbon deposits begin to gum the rings is about all—cleanliness, care and lubrication. Occasionally a ring will break and have to be replaced with a new one; then all of the broken pieces must be removed, even the smallest; otherwise they are liable to be ground into an abrading powder and will score or cut the cylinder.

Sometimes a ring may become weak in its outward pressure and cause leakage of compression and power impulse. While this soon means a new ring, a little longer service may sometimes be secured from the old one, at least through the emergency of the job in hand, by inserting a piece of clock spring or other light steel spring in the groove under the ring or by peening the ring. Broken connecting rods have been welded or united by means of riveted plates; but this is work for the shop and not for the novice; work, too, that should be done with the fact in mind that a break here may easily wreck the engine and the operator also. Piston-pins may be driven out when broken, and new ones substituted. Leaks and blow holes have been closed up in pistons by the autogenous welding process or tapped out and closed with plugs, although a projecting plug or bolt is always a menace, owing to its tendency to over-heat and cause pre-ignition.

Frequently a new engine will not run as smoothly

as one that has seen service; have patience till the bearing surfaces become smooth and reconciled to each other. Do not load a new engine too heavily while the bearings and reciprocating surfaces are still rough, or a seized piston may be the result. An engine under load has to endure a higher temperature than when running empty and it suffers greater expansion of its exposed metal parts.

72. **Other Troubles.**—Smoke issuing from the open end of the cylinder indicates a bad leak somewhere about the piston and may mean the loss of fully 30% of power.

Black oil running or dripping from the cylinder should set one looking for a broken piston ring.

Poor compression or shortage of power may mean only a stuck ring, caused by the gummy residue of combustion in the groove; or the edge of a ring or a groove may need a little grinding and polishing up with rotten stone and oil. Sometimes a little friction from rough ends at the ring joint is the cause of the trouble. High or low spots in cylinder piston are sure to be found by the explosive force hurled against them. If slight and in the piston the rings may overcome it. If in the cylinder and bad the cylinder may have to be rebored.

Most of this work requires special tools and a machinist's training and is not repair work for the farm shop. But for a properly designed engine, not overloaded and well cared for, such troubles come so seldom that they are not burdensome; while to depend upon untrained and inexperienced hands for the more serious repairs at this point is to hazard the safety of the entire engine.

73. **Hints and Suggestions.**—The piston is not sensitive, it is brutal, and when it goes wrong some-

thing serious is pretty certain to happen. A scraping or grating noise of dry metals rubbing together at each stroke means that the lubrication has failed. Don't wait to find out why; take it for granted there is a good reason—and shut down. If it is seen that the piston is drawing hard, better slow down as much as possible but still keep up motion until things can be cooled off a little or a seized piston may result. Of course the load must all be turned off at once and lubrication attempted, though the walls may be too hot to retain it in the usual way.

Sometimes a leaky piston is caused by the rings getting turned so that the joints of all are directly in line. Investigate and, in that case, turn them around; otherwise be careful not to disturb them. Not only will they fit best in the particular groove they have been occupying; they may refuse to work as well turned in any other way, and it is always best, where possible, to favor the whims of an engine that is working all right.

Barring accident, there is little to get wrong with the piston itself if it was made right in the first place. Nothing about it wears; it is protected from that by the piston-pin, the connecting rod and the rings. All of these may have to be replaced occasionally.

CHAPTER V.

THE PORT AND VALVE SYSTEM.

74. **Subject to Rough Treatment.**—While more engine troubles probably come from the ignition system than from all other sources combined, there is no other part which receives as much rough physical and chemical treatment for its regular heritage as the exhaust port and valve system; hence it is of special importance for the engine operator to understand just what the valves are for and how they ought to work; what troubles they are most commonly afflicted with and how to remove them.

75. **What the System Contains.**—In a general way, all engines require two openings or ports in the cylinder, an intake port for the admission of the fuel and an exhaust port for the expulsion of burned gases. The exact method of accomplishing these two processes may differ a little in different engines, some engines using two exhaust ports instead of one; but they all have the same results to accomplish and a variation in design represents, not different principles, but a difference in the ideas of individuals for getting at the same thing most effectively.

76. **The Intake Port.**—Through the intake port, which is situated in or near the closed end of the cylinder, a pipe leading from the carburetor discharges the fuel mixture into the combustion chamber, and it is the work of the valve at this point to open freely for the admission of this charge and then close ab-

solutely against any back leakage under the pressure of compression or combustion. This valve must work easily when opening, must close promptly, and its fit in the seat must be perfect.

77. **Size of the Intake Port.**—The size or capacity of the intake system fixes in some measure the amount

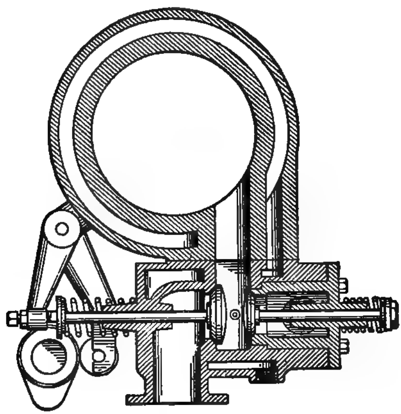


FIG. 22.—Cross Section of Valve Chamber.

of power or speed variation obtainable from an engine through varying the charge, and is of course fixed by the designer in the shop. While some departure may be allowable through a change in the frequency of the charges, the valve area provided by the maker of the engine is a fixed condition designed for a certain capacity, and is usually not so well adapted to any other.

Approximately, the size of the intake passage in usual engine practice is about as follows:

Diameter of passage equals that of piston multiplied by .316;

Area of passage equals area of piston multiplied by .1; or,

Intake passage area should equal area of piston multiplied by the speed of the piston in feet per minute; then divided by 6,000.

While the question of size is one for the designer rather than the operator, it is referred to here in order to emphasize the importance of keeping dirt and obstructions out of the passage and of keeping the valves opening to their full intended capacity.

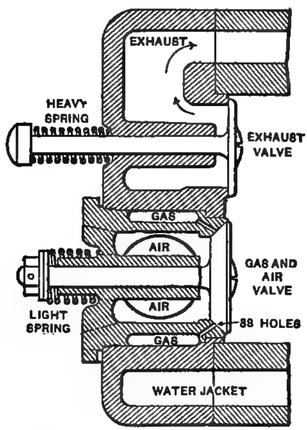


FIG. 23.—Sectional View of Combustion Chamber, Showing Arrangement of Valves In Cylinder Head.

78. Some Common Valve Troubles.—The three most common dangers from which the intake system suffers are dirt, leaks in joints or pipe, and worn or pitted valve faces. A very small obstruction, though not enough to close the passage against the fuel, may be a nucleus for the accumulation of other particles until the supply of vapor is reduced and the charge not sufficient; then the engine loses most of its power

even though it may continue to run. A much smaller particle of dirt carried along by the air current to the valve seat may hold the valve up a trifle from the surface against which it should rest; there is then a serious loss during the pressure of both compression and of combustion and a corresponding decrease of power. A bad leak of this kind may be rather difficult to locate, especially in a multi-cylinder engine, although bad leaks are rather prone to announce themselves by permitting a part of the firing flash to follow back through the valve and intake pipe to the carburetor. The result to the engine is much the same that it would be to a gun if the firing chamber was left partly open and a part of the charge allowed to escape without exerting any pressure against the missile. A single scale from a rusty pipe may in this way so far reduce the power of the engine as to render it incapable of accomplishing work for which under favorable conditions it would have ample power.

79. **Other Common Causes of Trouble.**—Faulty valve-seating may result from a weak compression spring or from the stem rubbing too heavily against one side of the guide, or by becoming warped from over-heat. The latter condition may only appear after the engine has become heated when running; or it may become a permanent defect. In the former case it is often specially difficult to locate.

80. **The Effect of Bad Air.**—The danger from dust-laden air drawn through the carburetor into the intake pipe and valve can hardly be overestimated. This is specially the case where the engine is set near an emery wheel or wood-working machinery, such as a turning lathe, where fine, light shavings and particles of wood are almost certain to be drawn in and deposited around the valve. Any considerable ob-

struction is likely to be noticed at once but the fine particles carried in from dust-laden air may settle and accumulate about the valve so gradually that the failing power of the engine is not noticed until it has become all but useless.

81. **Leak-Hunting.**—It is a curious fact that in a multi-cylinder engine the guilty cylinder may work faultlessly and cause one of its neighbors to do all the missing. A small leak is specially hard to find in slow speed engines. Leaks in the intake system are, however, much more serious in their effect than when in the exhaust, since they not only permit the escape of pressure but may so adulterate the charge with an improperly proportioned mixture as to destroy in a great measure the efficiency of the fuel that is used. Mis-firing often results from this, followed, perhaps by a cannonlike report which announces the accumulation of two or more charges in the muffler, where it may finally ignite all at once. More often though the unfired charge is merely expelled through the exhaust and wasted.

A leak should be strongly suspected if there is a tendency to back-fire or if the mixture is so weak that it ignites slowly and is still afire when the valve next opens to receive the succeeding charge. Often it can be located by holding a bit of flaming paper near the valve (having first removed the manifold), while someone hand-cranks the engine. Even a slight leak under pressure will be enough to flare the flame; or, if the engine is standing too near some stack or mow to permit of this method, the smoke from a recently extinguished stick is about equally sensitive to air currents. Often the leak can be located by covering the pipe with soapy water; then the issuing gas will appear in the form of minute bubbles or "soap-suds."

82. **Note Fuel Required in New Engine.**—Every engine purchaser should note carefully the amount of fuel consumed by his purchase, both running empty and under load, then make a record of the same. A decided change from these first results should set the operator leak-hunting and examining the valves and seats for carbon deposits or pitted faces. A little carelessness at this point may increase the running expense of the engine a fourth or more besides reducing its power by an equal amount.

83. **The Exhaust Port.**—The exhaust port is similar to the man behind the straw-carrier, upon whom all the soot and residue of the entire engine pours, so here is where leaks are most likely to occur. Here, instead of an occasional particle of rust or dirt, the valve is being constantly bombarded with all sorts of deposits which, owing to bad fuel, bad lubrication, or bad management, the engine has occasion to reject. It is the mission of the exhaust valve, after the charge is fired, to conduct all the burned gases and heated air from the combustion chamber in almost as brief an interval as the firing of the charge requires. More or less of this refuse is sure to be deposited with all that it touches and, in the presence of the extreme heat, is liable to be burned on. The hot gases, too, set up chemical actions which quickly pit the surface of the valve or warp it so that it does not seat properly. No part of the entire engine is given more continual abuse than the exhaust port and valve, and, in the presence of a mysterious compression leak, no other part should be more quickly suspected.

Usually the diameter of the exhaust port equals that of the piston multiplied by thirty-five hundredths, and its area the area of the piston multiplied by .12; or, the area of the exhaust passage should equal that of

the piston multiplied by the speed and divided by 5,100, the average speed of the exhaust charge in feet per minute.

84. **Inspecting the System.**—At least once a month, and oftener if the engine shows signs of low compression or general lethargy, the valves should be thoroughly inspected, specially with reference to their free action when opening and closing. If a valve seems sluggish, look to the compression spring; also notice whether the stems are wearing excessively by rubbing against the guides. If the valves or their seats are dirty, clean with kerosene or gasoline. If the faces are much pitted, regrind. If one side of the face is bright and the rest coated, see whether the heat has not warped it out of true.

85. **Valve Timing.**—Occasionally the valves show none of these defects and are still causing the trouble; they may be working out of time. When an engine leaves the works it is supposed to be properly set and the timing should not be interfered with; but after it has been used for some months retiming may be necessary; so every operator ought to know what the timing is for, and how it is accomplished.

86. **The Object of Valve Timing.**—As the piston starts upon its suction stroke the intake valve naturally opens to admit vapor into the vacuum created, though some engines secure more positive and quicker action by opening the valve by mechanical means; otherwise, during a fraction of the stroke the valve remains closed awaiting sufficient pressure to open it. During the suction stroke the fuel enters the combustion chamber through its narrow passage at a velocity of approximately 5,000 feet per minute and if the intake valve is held open a little beyond the end of the stroke this veloc-

ity will cause fuel to continue entering for an instant after the compression stroke has actually commenced. In other words, for an instant after the space is filled, the velocity will cause the gas to "pile up" if given a chance. It will thus be seen that mechanically operated valves have a distinct advantage over those worked by suction and compression alone, providing the cams which open and close them are set properly.

In most small engines the intake valve is opened by suction and closed by compression, which is hastened by a compression spring; then, so long as the valves work freely, the timing is automatic. The time of opening for the intake valve is rather less important than for the exhaust, though its closing time affects both power and speed.

Valve timing must not be confused with ignition timing. The spark must work in harmony with the opening and closing of the valves but the two timing movements are distinctly separate and should each be compared with the movement of the piston rather than with each other, as both must co-operate with that. A great deal of trouble may sometimes be avoided if well defined and permanent guide marks are placed upon the fly wheel and valve gear when the engine is in first-class working condition; in fact, many engines are now marked in this manner before being sent from the factory.

87. Testing and Setting the Intake Valve.—Revolve the engine fly wheel slowly by hand in the direction it should run until the intake valve cam barely begins to lift; then stop engine and note position of piston, which should have reached and passed by about ten degrees its extreme inner, or (in the case of vertical engines) upward, stroke. If much beyond

this position the valve is opening too late for insuring a full charge of fuel and the power of the engine is reduced. This may be due to improper setting or to a bent rod or to wear off the cam operating valve. To determine which, again revolve the engine, always in the same direction, and note the position of piston at the instant the cam roller releases the valve and permits it to close. If this occur before the crank has traveled 180 degrees from the point of opening the difference is due to wear or a bent rod as a rule; if the opening and closing points are 180 degrees apart the cams are all right and any error in relation to the time of the valve closing will be accompanied by a similar error in the time of opening; that means that the setting of the gear wheels is wrong and should be advanced or retarded, as the opening is too early or too late. Both the opening and the closing of the intake valve should take place with the piston 5 to 10 degrees past the inner and outer extreme center respectively, and it should remain open during a full 180 degrees of the revolution.

88. The Exhaust Valve.—Turn the engine, as before, by hand. The exhaust valve should open when the piston has covered about four-fifths of its outward and downward stroke and should remain open until within three degrees of crank travel from the point where the inlet valve begins to open, that is, barely past the extreme center of the return stroke.

89. The General Rule.—This allows us to formulate the time of opening and closing the two valves somewhat as follows: the intake valve should both open and close from five to ten degrees late, that is, beyond the exact stroke center. The exhaust valve should open early and close late in relation to the dead centers, its departure from the center being greater in

relation to its opening and less with regard to its closing time. Some engine makers so time the valves that the exhaust closes and the intake opens at exactly the same time, while in some of the high speed racing engines used in automobiles both valves are actually open for an instant at the same time, but this, while it may add a little to the efficiency of a high speed engine, is a distinct sacrifice of fuel to speed.

One other fault may affect the time when a valve operates. Between the top of the stem and the bar which depresses it there should be a slight clearance of 1-64 to 1-32 of an inch to allow for expansion of metal; otherwise when hot the stem may be in constant contact with bar and so kept from closing fully. This space, however, may in time be increased by wear and so compel the bar to move farther downward before the valve begins to open and be unable, in its limited movement, to open the passage wide. This would of course affect the work done by the valves and might reduce the power of the engine either by curtailing the inflow of fuel or by preventing the burned gases from being properly discharged. The amount of this clearance space should be noted occasionally both when the engine is cold and when it is at operating heat.

90. Valve Grinding; When and How.—Valves ought to be reground at least once each season, as the chemical action of the gases and the heat will certainly pit them more or less. Burned valves have sometimes to be ground much oftener, but it is well to remember that, like saw filing, the grinding of a valve removes a part of the metal, drops it deeper into its seat and advances the time when a new valve will be necessary, so they should not be ground any oftener than needed. The inlet valves do not as a rule need to

be reground as often as the exhaust valves, since they do not pit as quickly and are not so much inclined to warp with the heat. Valves should be examined once

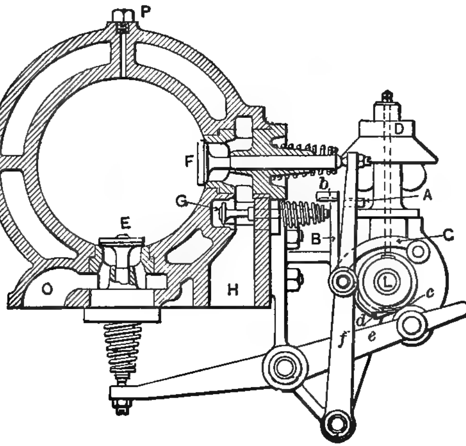


FIG. 24.—Typical Mechanical Valve Gear.

a month for pitting and the carbon should be removed from them with kerosene.

Fine emery dust and the finest grades of powdered glass made into a paste with lubricating oil are generally used, though many engine men object to even the finest emery as, once embedded in the metal, it tends to remain and continue the erosive action in the engine. At least, cheap emery should not be used, as the size of the grains varies so greatly. Care must also be taken that no emery is allowed to get into the cylinder. Emery cuts the fastest, while powdered glass, which looks like the finest flour, gives the most perfect finish.

To grind, remove spring from stem and cap from valve chamber. Apply semi-fluid paste of oil and

emery or glass on valve seat; then revolve valve with screw driver or by twirling stem between the hands. Do not use much pressure, but lift valve frequently to remove dirt balls. When it turns without much friction examine seat frequently and discontinue when there is a bright ring clear around, indicating that the surface is touching evenly its entire circumference. When finished give the final touch with tripoli and water. This insures a smooth face which will wear well. Wash in gasoline and wipe dry; then carefully remove all grit from the cage. Some valve seats are a part of the cylinder head but the better class are in a block, called a cage, which is removable like a spark plug. Test these after grinding by inverting cage after valve and spring are replaced, and filling with gasoline. If there is not even a sweating of gasoline between the valve and its seat when the valve is revolved the grinding job is perfect. Hand grinding, though slower, is the best method, though some use drill press or lathe. When hand grinding, motion should frequently be reversed. In drill press use slow speed and not much pressure, to avoid heating; also, release every few seconds. The job should not be regarded as complete until it will pass the above test with gasoline or at least will show a bright ring clear around both valve and the seat.

When valves are out notice whether the spindle has been worn smooth by rubbing hard against the guide. Polish the spindle with emery cloth.

Where emery is used in grinding, two teaspoonfuls of powdered emery in one pound of vaseline make a good mixture, but be exact with the measurement and clean the metal thoroughly after grinding.

91. **The Muffler; Its Use and Abuse.**—Few human made machines are so perfect that they do not include

some necessary evil. The muffler is the gasoline engine's Jonah, yet without it the entire neighborhood would soon vote the constant fusillade of cannon-like cracks a public nuisance.

A muffler of correct design and sufficient size to avoid back pressure may be made only a relative evil, although it is likely that the best of them destroy some power. By actual experiment a 36 H. P. engine running at 1,500 revolutions per minute, exhausting into the open air, became a little over 33 H. P. with exhaust pipes, and lost nearly 30 per cent. of power with both pipes and muffler.

Mufflers of greatest length and least diameter are most effective silencers—and power destroyers. They should not be too small or hampered by long exhaust pipes with many turns. The straightest course

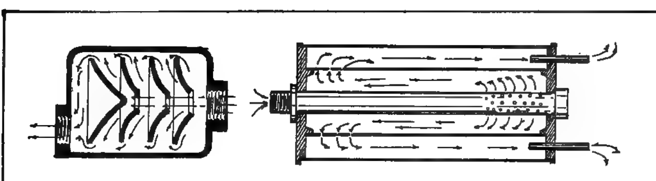


FIG. 25.—Sectional Views of Conventional Mufflers.

possible and with the least obstruction should be the rule with all exhausts, whether using a muffler or an exhaust or an exhaust pipe high in air. Some high, narrow pipes have actually been known to shut the engine down so that it would not run at all.

Dirty and obstructed mufflers must not be tolerated if the greatest power is desired. When the sound issuing from it resembles that of a continuous stream of compressed air the muffler is clogged with dirt or else some of the plates have been displaced. Remove muf-

fler and note result on engine. If it runs much better, clean and overhaul the muffler before returning.

92. **A Word of Caution.**—Never allow a gasoline engine to exhaust inside a stable or any other closed building where there is animal life. The burned out gases are in many cases active poison and live stock or human beings may be killed outright by the poisonous fumes. For this reason it is well to carry the exhaust well up in the air, but not through small pipe or one with many turns.

93. **Valve Vagaries.**—If the inlet and exhaust valves are on opposite sides of the cylinder head the spark plug points will remain much cleaner.

When the exhaust valves open too late the engine lacks speed; if they close too early it loses power, the plugs foul, the gasoline consumption is too high, the engine heats and does not throttle down.

Nickel steel exhaust valves resist heat much better than those of common steel, but do not wear so well. Latest automobile practice uses a nickel steel head electrically welded to a carbon steel stem.

Black smoke issuing from the exhaust indicates too much gasoline, and all the extravagance in fuel and dirt which goes with it.

Blue smoke means too much oil. Though less injurious, it should be corrected.

White smoke also means too much oil—and laziness in adjustment; or, it may mean water in the gasoline —that is, steam.

CHAPTER VI.

THE CARBURETOR.

94.—The Heart of the Engine.—Some one has called the carburetor a box full of mysteries with nothing in it. This is hardly true, but it may well surprise anyone who is familiar with the important function it performs to see for the first time the interior of this complicated looking contrivance. Instead of the handful of delicate wheels one almost looks for, the interior is about as simple and plain as the outside. However, more hidden mysteries and surprises await one in this little bundle of rigid pipes and outlets than in any other part of the engine excepting the ignition system. Here, too, lies the most vital difference between the gas, gasoline, and kerosene engine, where a little change may convert the one into the other. Here, too, without the proper special adjustment, a change of fuel may speedily convert an engine of one kind into none at all.

95. Carburetors to Be Let Alone.—Carburetors as a rule are adjusted before being sent out, so there is no excuse for meddling with them unless they meet with an accident or there is to be some radical change of fuel. To understand how they are constructed and just how they work when in good working order is essential. To know when to let them alone is at least equally important; often it is more so.

96. The Real Engine Fuel.—Neither a gasoline, kerosene, nor a gas engine can be run on the fuel

alone. All require air as a part of the combustible mixture, and it must be supplied in much the largest quantity of the two. Air alone would be quite as

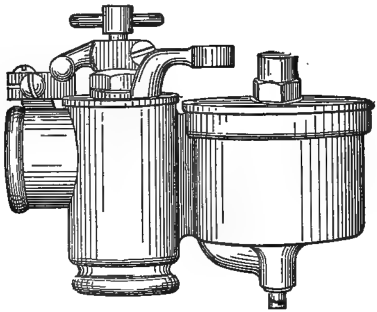


FIG. 26.—Exterior View of One Model Kingston Carburetor.

effective a fuel as gasoline alone, and gasoline cannot be used at all until it is converted into an air-like gas. It is the mission of the carburetor to so convert it

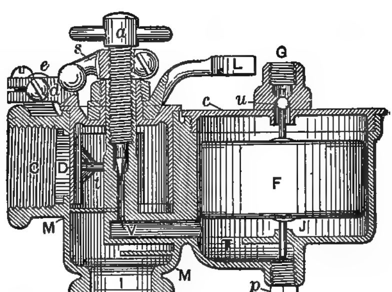


FIG. 27.—Sectional View of Kingston Carburetor.

and to mix it with the amount of air required for the best combustion; then to deliver the completed mixture to the intake pipe and from thence to the combustion chamber.

97. Why an Unvarying Adjustment Is Not Possible.—Theoretically, it would seem that the exact proportion of air and vapor which gives the greatest power could be determined by experiment, and then a carburetor made that would deliver this proportion always and no other. Mechanical mixtures, however, are never so constant in their proportion as are chemical combinations, and all petroleum vapors are in some measure mechanical blendings. Water vapor, carbonic acid gas, nitrogen and other more or less incombustible vapors are always present, but by no means always in the same proportion. Some of the burned gases from the previous explosion, too, remain in the cylinder, and the mixture delivered to the spark is sometimes very different chemically from that passed over by the carburetor, while the exact conditions under which it is fired may not be the same in any two consecutive charges.

98. How Fuel and Its Requirements Vary.—If there was not some range in the proportion of air and gasoline vapor that can be ignited the gasoline engine would hardly be possible. Air mixed with 1.25 per cent. of gasoline will barely ignite at atmospheric pressure; then the vigor of the combustion increases steadily until about 2.5 per cent. of gasoline is introduced, when it diminishes again until at about 5.5 per cent. it again becomes non-inflammable. Greater heat permits the use of a somewhat weaker mixture, and it sometimes happens that the fuel which is right for starting the engine up when cold becomes too rich after the metal has become heated. High compression also makes the use of a weaker mixture possible, so that a part of the energy lost in the extra compression is made up in the increased economy in amount of fuel. The mixture which is correct at nor-

mal speed is, on the other hand, too weak for low speed.

99. How the Carburetor Vaporizes the Gasoline. —When the piston starts upon its inhaling stroke it leaves a partial vacuum behind it, and the intake valve,

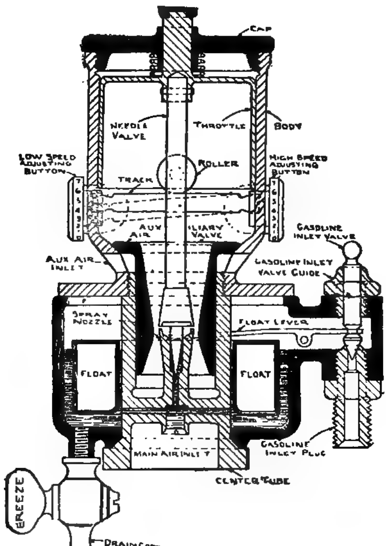


FIG. 28.—How the Carburetor Vaporizes. Sectional View of Breeze Device Shows Important Parts.

responding to the suction, admits a current from the pipe back to the carburetor, where an opening admits a supply of outside air. This action serves two purposes. Not only does a current of air begin to rush into the cylinder and fill the vacuum, but in passing across the surface of a shallow pool of gasoline in the carburetor, it turns a portion of this into vapor and carries it along as we have seen a current of heated air evaporate a saucer of gasoline in the sunlight

when the wind is blowing across it. It is this property of ready evaporation that makes gasoline specially adaptable to use as an engine fuel.

100. **Mixing Air and Gasoline Vapor.**—Some engines accomplish the mixture by the mere act of drawing the air current across the surface of gasoline, while others depend upon spraying the liquid through a fine nozzle into the midst of the current and so present in the form of mist a relatively large surface area of gasoline to be acted upon. With the known area for the admission of air the flow of gasoline may be so regulated that the resulting mixture will approximate that point at which the combustion possesses the most energy. A float valve made of cork or light metal cylinder or can, hollow and air-tight, regulates the flow of the liquid into the float or receiving chamber by connection with the inlet valve, which in turn cuts off or admits more gasoline as the supply rises above or falls below a certain level.

101. **Automatic Carburetors.**—Automatic carburetors are intended to partially close at low engine speed and gradually open as the speed increases. They are specially essential when the load thrown on the engine is likely to vary considerably, as it does in much farm work—such as hay pressing. Formerly it was thought that the best carburetor was the one which did its work with the least possible variation, but it is known that where the load varies the supply of fuel should fit the work it is intended to do.

102. **Bad Air.**—It is easy to see the importance of keeping dirt out of the pipes and valves by keeping the gasoline free from dirt particles. That the air supply needs to be equally well guarded does not appeal to some. If the engine gets its air supply from a dusty barn or workshop and there is no trouble

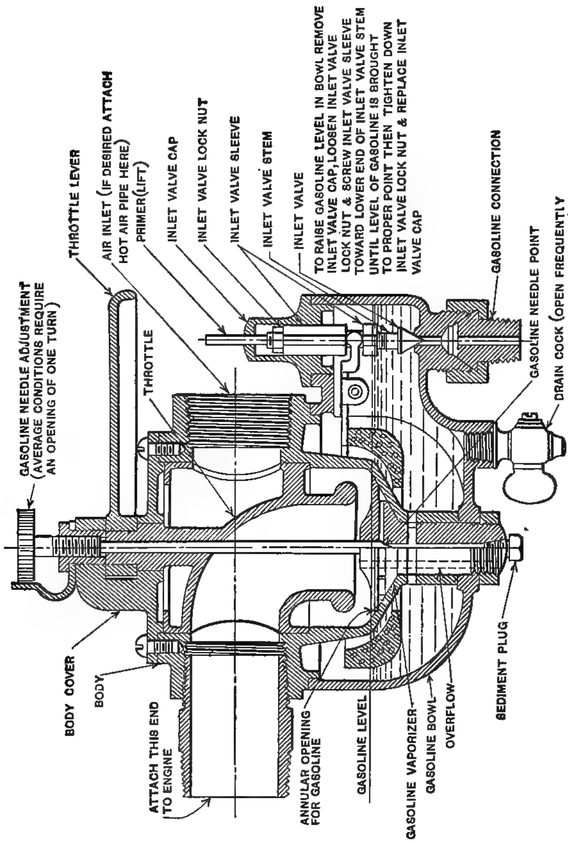


FIG. 29.—Sectional View Showing Parts of Krice Carburetor.

some place along the intake pipe, we may be sure that sooner or later the gradual accumulation will be heard from in the valve seats. The air that an engine breathes should be as free from dust as the gasoline is from dirt; and, in cold weather, there will be a saving of energy if the air be warmed somewhat before it reaches the cylinder. This is imperative in the case of kerosene engines, as kerosene requires a higher temperature for vaporizing than does gasoline. kerosene engines, for that reason, are generally started on gasoline until the metal has time to warm up; or the carburetor may be warmed by direct heat, and the trouble of using the two fuels avoided.

103. **Carburetor Troubles and How to Cure Them.**—Nearly all carburetor troubles come from one of two avoidable faults; incorrect mixtures, and dirt. Temperature troubles may arise, but are so well understood that there is little mystery about them. Always, when dealing with gases in pipes open to the outside air, atmospheric pressure will keep a full supply of something constantly coming over. If one of the gasoline pipes happens to get half clogged with dirt, the place of the gasoline vapor is taken by a greater proportion of air, and the same amount of mixture seems to be coming into the cylinder. The fuel will be too poor or weak, though; the explosions will lack force, or possibly miss fire entirely until an accumulation of the unexploded charges may lodge in the muffler and make a startling report to the man outside.

104. **Barking.**—This is called barking or after firing, and should not be confused, though it often is, with back firing. Barking may be due to either too rich or too weak a fuel. It always indicates misfiring or incomplete combustion. The remedy is ob-

vious; find out what is wrong with the mixture and correct it.

105. **Misfiring.**—Misfiring may be the result of anything which renders ignition difficult; either too weak or too rich a mixture often causing it. It is also caused by various ignition vagaries. If the mixture is too rich, more or less black smoke will be seen to roll out of the muffler. If this is not present, gradually increase the gasoline supply until the misfiring disappears, or else the black smoke becomes visible. If the latter occurs first the misfire is not due to carburetor trouble. Sometimes a leaky intake pipe causes misfiring by the admission of air which dilutes the correctly proportioned mixture delivered by the carburetor.

106. **Back-firing.**—This rather startling accident is as a rule more exciting than dangerous, and is often caused by too weak a mixture which does not ignite readily and burns so slowly that the cylinder holds the fire until the valve opens to admit the next charge; the combustion flashes back along the incoming charge toward the carburetor. Like all other mixture faults, the remedy is to correct the defect.

107. **Flooding.**—When for any reason the float ceases to shut off the supply of gasoline at the right time, flooding is sure to result. The failure may be due to the imperfect seating of the float valve, either on account of a grain of dirt or an imperfect fit. If the latter, a light grinding of the valve in its seat with or even without abrasive paste will probably overcome the difficulty. If dirt is lodged under the float, depressing it repeatedly may wash out the obstruction. Occasionally the coating of a cork valve breaks down and permits the float to become soaked until inclined to sink too low in the liquid. In the

case of metal floats a leak may bring the same result; then the liquid is allowed to rise too high in the chamber. All of these causes, of course, suggest their own treatment. The presence of liquid inside a metal float is evidence of a leak, and the leak may generally be located by heating the float and then applying a match to the side until the issuing jet of gas is found.

108. **Priming the Carburetor.**—The occasional necessity of this arises from the fact that the supply of gasoline has to be higher in the float chamber in starting an engine than after it is warmed up by running. In the top of most float chambers is a pin by means of which the float may be depressed and an excess of gasoline allowed to enter. This is called priming the engine or "tickling the carburetor," a process generally overdone. A slight depression is enough to start the flow, while a continuance soon floods the chamber and renders a mixture so rich that frequently the engine refuses to start. A steady depression, too, is quite as effective as a series of hard, sudden jabs, such as many people use; and is far less likely to do an injury.

109. **Size of the Carburetor.**—As a rule the engine purchased for the farm is already supplied with a carburetor; still it is not always fitted with one; for a carburetor, like any other vital part, may easily be too small; while, on the other hand, it may be too large.

If too small, it cannot deliver in sufficient quantity the mixture of fuel vapors which mean the power of the engine. If too large, so that a greater quantity is presented to the intake valve than it is capable of admitting, the speed of the current is so far reduced that the process of evaporation may be seriously interfered with and a poorly proportioned mixture be

the result. In another chapter is given the formula for finding the effective valve area, and the carburetor with an outlet diameter slightly larger than the valve area will be the best size, a little excess being allowed to overcome friction of the fuel in passing through carburetor and pipe.

110. **Adjusting the Carburetor.**—With so many different carburetors on the market it is difficult to lay down rules for adjustment that would apply to all, or even in all cases to any one. The air valves of automatic types are intended to close at lowest engine speed and to open by degrees until the maximum opening is reached at the highest speed. The maximum lift, of course, depends upon the size and speed of the engine. There is usually a stop, which is adjustable, to prevent fluttering and to control the maximum opening of the valve. This should be carefully adjusted. Usually a needle valve of some sort regulates the liquid entering the spraying nozzle. This should be adjusted until the engine runs best at its lowest speed with throttle as nearly shut as possible. The throttle should then be gradually opened and the tension of auxiliary air valve increased or diminished slowly until the best average running condition is found; then at high speed a slight readjustment of the needle valve may be some improvement. If maximum speed is desired, a little wider opening of both needle valve and auxiliary air valve should be given than for ordinary running; but this is a sacrifice to economy of fuel and the engine will be harder to start. The auxiliary air valve screw should be used only to hold valve on seat with enough pressure to keep it there under lowest throttle. The valve movements should be controlled by size of the spring, either through a change in the size or number

of coils, and not by tightening or loosening the screw.

111. **Adjusting the Float Valve.**—With the float valve chamber filled to the point where shut off by the float, notice whether there is a continuous dripping from the spray nozzle and, if there is, press the valve shut and see if the dripping continues. If it does the valve does not shut properly; if not, the liquid is too high in the chamber and the float valve should be adjusted to shut it off sooner.

Carburetor adjustment is a delicate thing which needs both care and some little skill. It should not be attempted by the novice unless absolutely necessary. When it must be done, attempt but one adjustment at a time and, when the points are finally found in all the adjustments where the engine runs the best, in some way mark the places so as to save complete re-adjustment if the carburetor should ever be disarranged. A small, simple mark may be the means of avoiding a very difficult task.

112. **Miscellaneous Hints.**—Most leaks in the gasoline system occur near the carburetor and are caused by the continuous vibration of the engine while running. They seldom develop near the tank except in case of a direct injury or accident.

Sometimes there is a point in the overflow pipe lower than the tank wherein the gasoline will be trapped. The overflow pipe should have a distinct pitch toward the tank.

The flow of the gasoline through the pipes is so slow that all dust has a chance to settle to the bottom rather than be carried along. This renders straining all the more necessary.

Occasionally set drip pan under carburetor, if for no other purpose than to see for certain it is not leaking.

Always have a good stopcock on the line somewhere between tank and carburetor. Do not depend upon the carburetor to shut off the flow when the engine is standing idle.

Gasoline which has stood long in the carburetor while the engine is idle may become stale and lifeless; then it must be drawn off and new gasoline substituted by priming before the engine will start readily.

Back firing is sometimes caused by too close needle valve, as well as by water or dirt in the gasoline; in fact, anything which so reduces the supply of gasoline that the fuel mixture is too poor may be the prime cause of a back fire.

Occasionally a continuous spray is thrown from the inlet. A larger pipe for the air inlet may remedy this; if not, discard for a new one.

If the correct mixture at normal speed is too rich at low, release auxiliary valve spring a little; if too weak, increase tension on spring. If this makes spring too stiff for ordinary speeds, reduce needle or enlarge intake opening slightly.

CHAPTER VII.

THE IGNITION SYSTEM.

113. **Difficulties of the Problem.**—To fire a single charge of fuel mixture is a simple matter. To introduce and extinguish from one hundred to fifteen hundred separate flames per minute into the same receptacle used for receiving and compressing the gas at just the right instant to ignite the charge at the moment of complete compression, without missing a charge, is entirely beyond the working possibilities of any igniting agent known to man but the electric spark.

114. **The Effect of Failure.**—The occasional missing of a charge not only entails a waste of fuel and power which becomes more and more serious as the size of our engine increases; it leaves a portion of the missed charge to accumulate in the cylinder to preignite or to form too rich a mixture with the next charge, or to ignite later in the muffler, creating back pressure and making an active working force against the power of the engine.

115. **The Open Flame Method.**—The problem was first met by the use of a continuous igniting agent which was shut away from the cylinder excepting at certain points in the cycle of the engine. The idea has been fairly successful, though more or less trouble arises from the fact that no separating device has been obtained that is absolutely instantaneous in its action, and the operating delay increases with the

soot and dirt accumulation of actual use. Still it was with the aid of this system that the first gasoline engines were made to run.

This is referred to merely as a matter of history; it is no longer of mechanical importance, as the method has long ago been abandoned. It was found that the exploding impulse of the engine, as well as outside disturbing elements, was likely at any time to extinguish the flame; hence the system required constant attention and was even then unreliable.

116. **Hot Tube Ignition.**—This has been fairly suc-

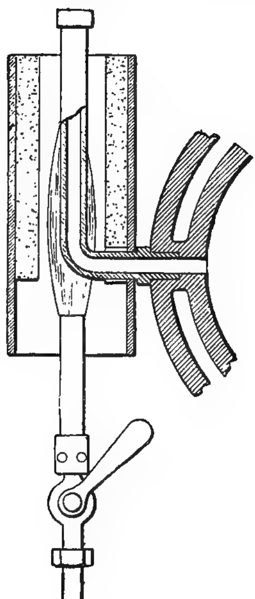


FIG. 30.—Bent Hot Tube Igniter.

cessful and, though nearly discarded for the electric spark, enough hot tube engines are still in use to

merit attention. As first produced, an iron tube was heated by means of a Bunsen burner flame and the heat conducted by means of the iron tube to the igniting chamber. In this way the flame itself was protected from the blast of the explosion. The intense heat and pressure, however, caused the tubes to break down from very brief service, and porcelain has been substituted for iron. These do not oxidize and, though somewhat easily broken in the setting or through accident, when once in place, they frequently last for a year or more at a less cost than for a single cell of dry battery.

Nickel-alloy rods are now the favorite with hot tube engine men, as their life is even greater than porcelain and they are not so apt to be broken by accident.

The hot tube system is confined almost wholly to stationary engines in the oil fields and elsewhere, where fuel is cheap and the speed irregularities due to missed charges are not important.

117. **Firing by Compression.**—The compressing of gas raises its temperature, and some have hoped to use this very feature, which limits the compression possible to give gasoline without danger of pre-ignition, for the purpose of firing the charge at just the right moment. This would do away with the entire electrical ignition system and at the same time allow greater compression. While experiments along this line have been quite successful, the device as yet is not in general use.

118. **Firing by Electricity.**—Nearly all gasoline engines of the farm type are fired by electricity, the only known igniting agent that is quick enough and dependable enough to fire every charge of an engine at high speed. Perhaps the greatest objection to it is the special electrical knowledge which the operator

needs, and which even the trained general mechanic may not always possess. For this very reason, more electrical troubles arise than in all other parts of the engine combined and they are harder to locate because the current itself is invisible.

119. **Gasoline Engine Electrical Knowledge.**—Without attempting to go into the details of electricity, the electrical appliances in common use in engine ignition will be named, briefly described, and their exact uses designated, always with a view to being practically rather than scientifically accurate in terms.

120. **The Four Electrical Processes and Their Agents.**—1st. Producing the current. Agencies, battery of cells, wet or dry (the chemical process), or the magneto or dynamo (mechanical process).

2nd. Intensifying, either by means of the spark coil or in the magneto itself as sometimes made.

3rd. Conveying the current. This includes wires or cable of both high and low tension, the switch, binding posts, and terminals, and distributor.

4th. The current breakers, which change the invisible current into a point of intensely hot spark.

The general meaning of all of these should be familiar to all engine men.

121. **Producing the Electric Current.**—Two methods are in use for the production of the electric current; from a battery (usually composed of dry cells) and by means of a magneto. The latter is practically a small dynamo, which is run at high speed by being belted or geared to the engine, either with tooth or friction gear.

122. **The Dry Battery.**—A dry battery consists of two or more dry cells (usually four to six in a gasoline engine), connected by wires so that all the cells

act together as one, but with united intensity. Each cell is capable of producing, when fresh, about 1½

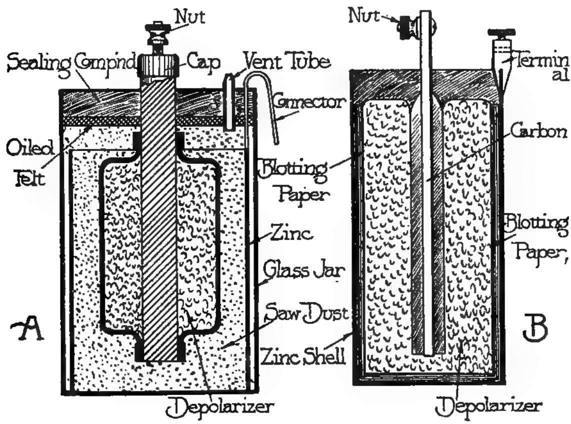


FIG. 31.—Sectional Views of Standard Dry Cells. A—European Construction. B—American Design.

volts of electric current through a union of chemical and mechanical action.

123. **What the Cell Contains.**—The cell as usually made consists of a zinc cup about six inches long and two and a half across, open at one end. This is the positive element of the battery, from which the negative current is obtained. An inch of pitch or some non-electrical conductor covers the bottom; then a carbon rod in held upright at the center and the space around it packed with manganese dioxide or some other depolarizing material, then filled with sawdust or some good absorbent over which a solution of 25 per cent. to 30 per cent. of sal-ammoniac and water is poured to saturation. The top is sealed with pitch and the outside usually wrapped with light strawboard. A binding post at the edge of the cup and

the top end of the carbon form the two poles of the cell.

124. **Connecting the Cells in a Battery.**—Unscrew the cap from binding post of a carbon rod and wrap a short piece of insulated copper wire, with the end scraped bare and bright, tightly around it in the direction the cap turns to tighten; then return cap, screwing it down firmly to insure good contact. Fasten the other end of the same wire in this manner

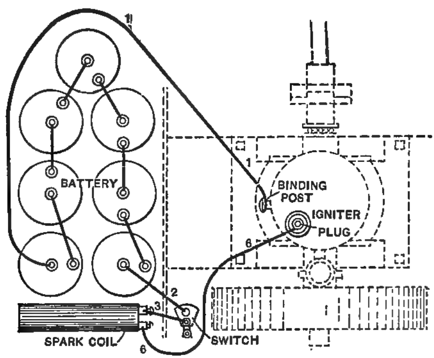


FIG. 32.—Showing Dry Cell Battery Wired in Series.

to the zinc cup of the next cell. Connect all the cells in the same way, always joining zinc to carbon. This is called connecting in series, and the whole number of cells connected form the battery. It is not correct to speak of a single element or cell as a battery. The wire for this connection should be at least No. 14 (though No. 10 or 12 is better) and must be insulated or the current will short-circuit, just as water, circulating through a network of pipes, would take the shortest course that was open to it.

125. **Life of Dry Cells.**—The life of a dry cell is uncertain with the best of care. One cell may become

exhausted in a few weeks and another of the same make last as many months. Abuse soon exhausts them, such as connecting them up with a spark coil for an interesting display of electric sparks. One run-down cell in the battery weakens the rest and should be removed. Under fair treatment the average life of a fresh cell is probably between three and six months, though many fail before that time and some have gone much longer.

126. **Advantages of Dry Cells.**—Their first cost is very light, from 25 cents per cell up. They are simple and easily connected and, if let alone, do not get out of order easily. They may be obtained of any electrical supply store and may be installed by any one. They are ready to produce a spark with the first revolution of the fly wheel; are clean, reliable when fresh, and not easily broken.

127. **Their Defects.**—They are uncertain of life and not generally counted reliable after a month old, although the writer has secured good results from cells that had been in the engine (though not in steady use) for over a year. Often a cell will become worthless even with the engine standing idle. In the end they are expensive because of the constant renewals.

128. **Care of Dry Cells.**—Dry cells should be kept in a box by themselves, and other things kept out of it. Pieces of wire or metal tools may easily form a short circuit and run the cells down very rapidly; so may dampness; they must be kept dry and cool. Where in constant use, two sets so wired that they may be used alternately will greatly increase the life of both. For instance, by placing two sets of six each wired up as two separate batteries and used on alternate runs, both sets will last much longer.

129. **A Good Battery Arrangement.**—A plan in use

en some of the motor boats of the United States sea service is worth giving. A battery box of galvanized iron is made just large enough to hold twelve cells and hot paraffine poured into the bottom. On this the cells are set in their paper cases, and two or three inches of paraffine poured around them. They are then connected, six in series, and the two batteries used alternately an hour at a time. A lump of lime laid in the box will absorb all moisture. Used in this way, cells frequently stand the hardest kind of continuous ocean service for a space of six months.

130. **Connecting Battery to Engine for Spark.**—A battery of six cells ought to give about nine volts of

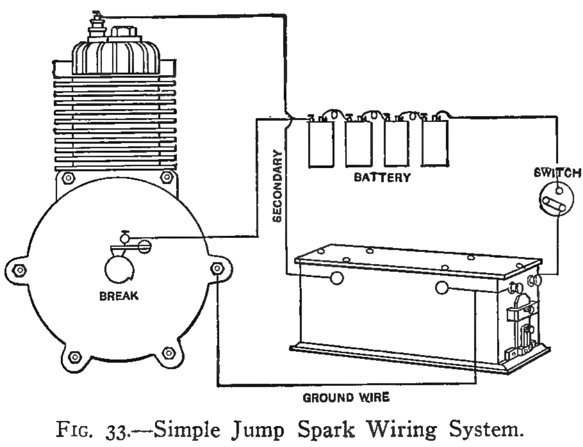


FIG. 33.—Simple Jump Spark Wiring System.

electric energy. Connection is made with wire from the terminal carbon to the positive binding post of the spark or induction coil through the primary circuit, which carries the direct current from the batteries. The negative post in this coil leads to the timer and the positive pole of the battery connects with the iron

of the engine frame, which, being a conductor, forms a part of the circuit through the timer. From the negative pole of the secondary circuit, the high tension wire, the current goes to the spark plug, which is usually located in the end of the cylinder.

131. **The Spark Coil.**—This is really an induction or Ruhmkorff coil placed in the path of the current to store and intensify it. It consists of a magnetic core containing many turns of insulated wire wound like a spool of thread. The secondary or high tension current is much more intense than the primary, and

FIG. 34.—Jump Spark Vibrator Coil for One Cylinder Ignition.

gives a much hotter spark. This spark coil is rather a delicate affair, which should only be disturbed by those who fully understand it. Though it contains little that is likely to get out of order, a break in any part of the insulation along its many coils of wire would cause a short circuit and make rewinding necessary. About all the care a novice is called upon to give it is to see that water and abrading substances are kept away from it and that the connections, sparking points, etc., are kept clean and bright. The system of connecting here given is specially intended for the jump spark or high tension method of firing.

132. The Spark Plug.—Reference to the illustration will show two platinum wire points at the inner end of the spark plug which, together with the insulating substance, comprise the essential parts. One of these wires, cut off from electrical connection with the other and with the rest of the plug by the insulation, is attached by means of the binding post at the top with the high tension cable; the other is in direct communication with the cylinder and engine frame.

133. How the Spark Is Formed.—So long as an electric current can pass without interruption along

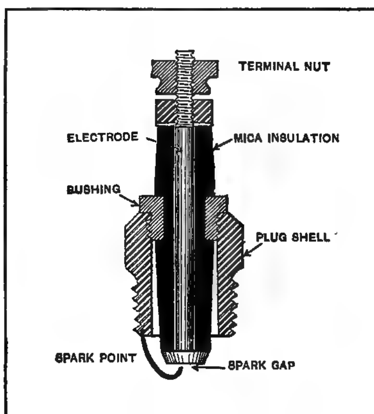


FIG. 35.—Sectional View of Spark Plug.

a good conducting medium like copper wire, it is silent and invisible. It is only when we obstruct its passage by throwing a non-conductor in its path that it attempts to break down the opposition, just as a creek will try to leap over the dam that stops its course. A broken circuit with a layer of air between the ends forms such an obstruction. If the ends are reasonably near and the current is strong, it will undertake

to jump across the gap, carrying minute particles of the metal along with it and heating these and all floating particles in the air to a white heat as a proof of the energy it has made use of in jumping the gap. This is the spark we see.

134. **How It Fires the Charge.**—No amount of electricity passing along a wire of sufficient carrying capacity would cause an explosion in a keg of gunpowder so long as it was not interrupted; in fact, it is not the current itself that does the igniting but the floating, heated particles where the break is. The only difference between this and hot tube ignition is that the tube is heated in the one case and the floating particles in the other; but the heat from the spark is much more intense and easier to regulate. When the timer closes the circuit and allows the current to pass through the wire it is suddenly interrupted by this air gap between the platinum points and, if the current is strong enough and there is a space of only about 1-32 to 1-16 of an inch between the points, it leaps across, heating the particles in the air to a white heat. This heat is sufficient to ignite the fuel vapor.

135. **The Jump Spark.**—This is the so-called jump spark or high tension system, and on account of its simplicity and ease of operation, it has rather the lead among enginemen, especially for farm work. There is little about it to get out of order and, when the points become worn, as they finally will, under the repeated heating, the spark plug may be renewed for something like a dollar.

136. **The Make and Break.**—Some engines use the make and break or low tension system. This consists of two metal points inside the engine cylinder, one of which is movable and is operated by mechanical means. These points are usually in contact, and a current of

electricity passing through them is not interrupted as by the air gap in the spark plug; then, at the moment when the charge is to be fired, the contact points are pulled apart and when the contact is broken a spark leaps between the two points. The make and break system furnishes rather the hottest spark, and the efficiency of an engine has frequently been increased by substituting it for the jump spark system. The points and sliding mechanism are more liable to get out of order than stationary points, in the presence of carbon accumulation and intense heat, and are less accessible for cleaning or repairing than the plug, which screws into the cylinder at the top. For these reasons principally, the jump spark method seems to have the call among the non-professional engine owners, while very many of the experts favor the make and break system because of the more dependable service obtained from

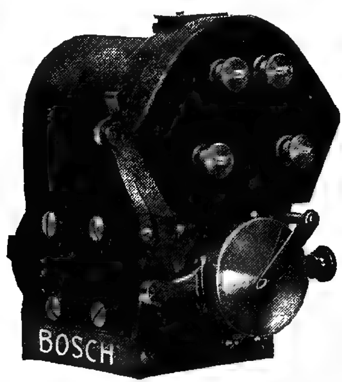


FIG. 36.—Bosch Magneto, Exterior View.

the hotter spark in the presence of variable or faulty mixtures, and the increased power given the engine by firing the charge more promptly at the most efficient moment and condensing the time of impulse.

137. **The Magneto.**—Although the first cost of the magneto is several times that of a battery of dry cells, it is cheapest in the end for a good engine, as, once installed, it requires practically no attention or renewal expenses for years. It also gives a hotter spark and greater engine efficiency, especially under adverse conditions of fuel or temperature where firing is difficult. For an old or cheap or worn-out engine the expense would hardly be justified; nor possibly for one which stands idle a great part of the time. Aside from the greater efficiency of the hotter spark, the question is one between first cost and maintenance cost, of which the first has to be met but once and the latter is continuously to be reckoned with.

138. **How It Works.**—It differs from a dynamo in

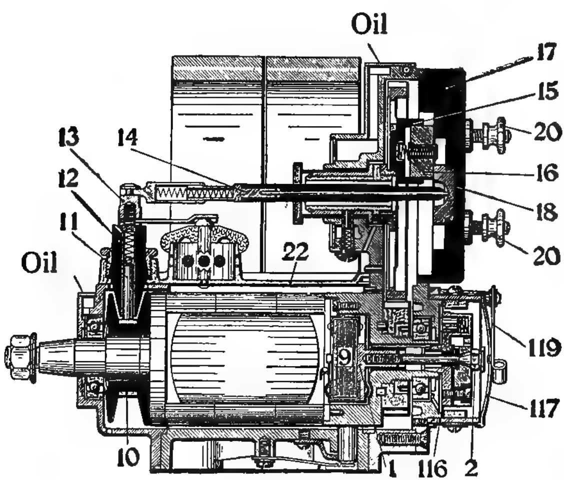


FIG. 37.—Longitudinal Sectional View of Bosch Magneto.

principle mainly in that the armature revolves between permanent field magnets of steel instead of electro-magnets consisting of a soft iron or steel core

wound with wire. Because of this difference, the magneto may be run at any desired speed or the speed may be varied, while that of a dynamo must be constant.

A handful of wire nails, each brought in contact with a common horseshoe magnet, becomes a separate magnet which may be used to pick up small metallic

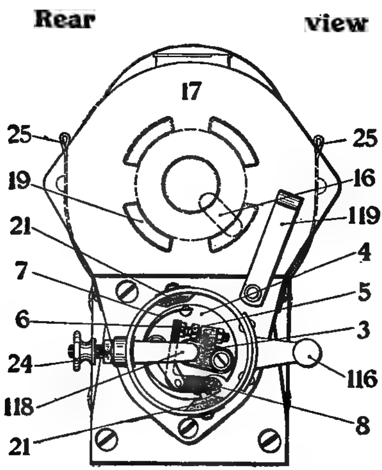


FIG. 38.—Rear View of Bosch Magneto, Showing Contact Breaker and Distributor.

objects. If a wire be wound loosely around the magnet without touching it, each coil of the wire may be said to have become a separate magnet and the total strength of all these separate magnets will make up the strength of the so-called magnetic field. If a soft iron were substituted for the magnet and a current of electricity passed through, the magnetic action of the surrounding coil would be much more intense, but would only remain while the current was passing, while the magnetism set up by the steel, though less

intense, remains in all parts of the coil on which it has exerted its influence. This second magnetic or electric action set up in the coil is called an induced current because, instead of being created by direct contact with some source of electrical or magnetic fluid, it has been influenced or induced into existence.

By increasing the number of turns of wire in the coil and revolving it rapidly between magnetic or electrical fields, this induced current may be greatly strengthened until what began as a feeble magnetic impulse in the magnet finally becomes an electric current of considerable intensity. The armature on which this coil is carried is wound in two parts, the first consisting of a few turns of coarse wire, and the second of many turns of fine wire, all of which has to be insulated with some nonconductor of electricity its entire length. The electrical influence or current set up in this coarse or primary winding, as it is called, is frequently interrupted by a mechanically operated circuit-breaker, so that the current is allowed to flow only by short jerks. These interruptions to the primary current set up an induced current in the secondary or large coil of fine wire which, intensified as it is by the hundreds of turns of wire, becomes so intense that, when it presently passes over the high tension cable to the spark plug and there finds a break between the firing points, it promptly leaps the gap, forming an intensely hot spark.

As this spark is only produced by the breaking of the primary circuit it is necessary for the magneto to be set in definite relation to the crank shaft of the engine, so that the break will occur at the instant the engine piston is at the right point for the firing of the charge. This calls for positive drive, and belt or friction drive, possible with dynamo, cannot be used in

connection with high tension magneto. Just why this secondary current is induced when the primary current is interrupted would require pages of explanation. Electricity, however, is a lazy fellow so long as things run smoothly. It is when he is interfered with that he puts forth his energies and does work or exerts useful energy. The above description is of an alternating current, high tension magneto, suitable for the jump spark system of firing with spark plug. They are driven by suitable worm, spur or bevel gears from the crank shaft of the engine and, once installed, need no attention for years beyond an occasional oiling of the bearings. Some of them, like the one described, have a revolving armature. In others the armature is stationary, while the magnets revolve.

139. **Low Tension Magnetos.**—The low tension magneto is for the make and break system of ignition, in which the current does not have to be intense enough to jump a gap, but simply follows out the moving point for an instant as the contact is broken, forming a short electric arc. It is also used for the high tension or jump spark system in which is installed a separate intensifier or spark coil. It works like the high tension magneto excepting that there is no secondary winding, while the one coil of wire consists of moderate-sized wire.

140. **Care of Magneto.**—In general terms the less attention the magneto gets from the amateur the better, for only an electrical expert understands how to reassemble them. All the parts which ordinarily need readjustment are easily accessible; the rest should all be let alone. A little oil should be used on the parts where it was intended, but oil dropped carelessly on the coil softens the insulation and may easily ruin the winding. Water may cause short circuits also.

While most magnetos are regarded as water-proof, the term is only relative and intended for emergency safety only, not for weeks or months of exposure to the weather. Rust also attacks the connections. If properly cared for the winding of a magneto ought to be good for three to five years and the magnetic field

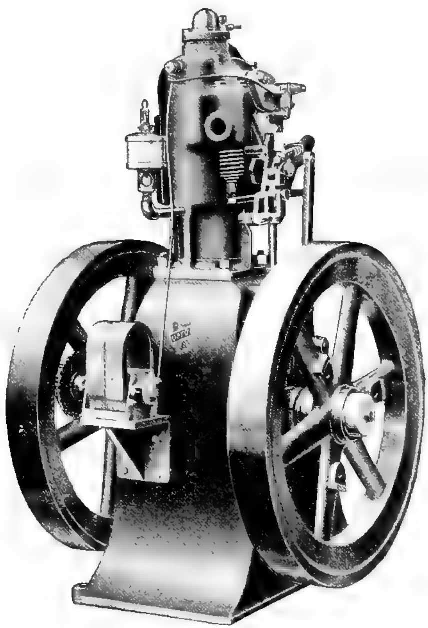


FIG. 39.—Showing Ignition Magneto In Place on Engine Base.

should last from eight to fifteen. Even then it can be renewed for a dollar or less. If the spark becomes uniformly weak the magnets may need remagnetizing or a winding may be broken down at some point. This is not a repair job for the amateur, but before sending the magneto back to the works for repairs be certain that is where the trouble is located. Manu-

facturers say that at least fifty per cent. of the magnetos and coils sent back to the shop for rewinding are all right and that the trouble is in some other part of the engine.

141. **Where the Double System Is Best.**—Not all magnetos produce a spark with the first revolution of the fly-wheel; some are even reluctant about sparking at all under the low speed available while

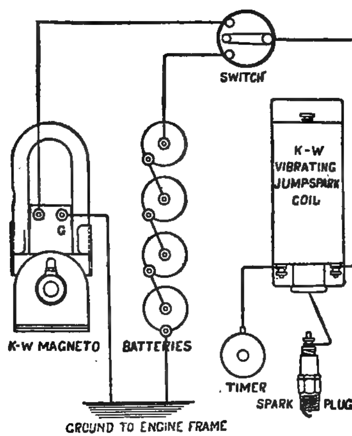


FIG. 40.—Simple High Tension Wiring System, Using Batteries and Magneto.

the engine is turned by hand. In other words, the spark is not produced until the engine starts and so runs the magneto, while the engine will not start without the spark. Some operators use a double ignition system. A battery of dry cells is installed to start the engine; then it is switched off and the magneto used the balance of the time. This makes a very satisfactory combination, though with some of the better grade magnetos now on the market the spark

is produced so promptly that the auxiliary battery is not needed.

142. **What the Primary Circuit Includes.**—The jump spark or high tension system has both a primary and a secondary circuit; the make and break usually but one. The primary circuit includes the battery, the primary or inner wire coil of the induction coil, the contact breaker or buzzer and the commutator or timer. Its object is to magnetize the core of the spark coil and, after the current has been set up, to operate the contact breaker or vibrator and set up a secondary induced current by the interruption of the primary circuit.

143. **The Secondary Circuit.**—This includes the fine or secondary coil of the induction coil, and the spark

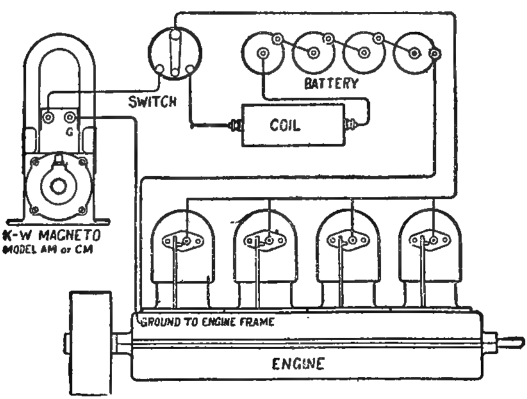


FIG. 41.—Low Tension or Make and Break Spark Wiring System, Using Magneto With Batteries as Auxiliary Source of Current.

plug, and high tension cable. Its mission is to intensify the primary current by induction, and to convey it to the engine cylinder, where the spark gap that fires the charge is located.

144. The Wiring System.—The wiring system should be short as possible and of heavily insulated wire or cable. The best high tension cable used in connecting the spark plug with the coil is much larger than the lower-powered conductor and consists of a number of tinned copper wires, often as many as twenty, twisted together and covered by successive

FIG. 42.—High and Low Tension Current Conductors.

layers of insulating tape. The low tension wire connects the carbon terminal of the battery with the positive pole on the coil. It usually consists of several fine copper wires, around which several layers of insulation are wound. A second wire of the same material runs from the negative pole of the battery to a ground connection—usually the frame of the engine. From the negative pole of the coil a third wire connects with the timer.

It is important to see that all of these wires are thoroughly connected with clean contacts, and the nuts on the binding posts screwed down tightly, and that the connections are free from rust. A good varnish for the terminals may be made of sealing wax dissolved in gasoline, with enough linseed oil to prevent its being brittle. Short circuiting is sometimes caused in damp or foggy weather by a drop of water getting in below the fly nut holding the high tension

cable, and across the porcelain of the plug and hence to frame.

145. Ignition Timing.—Ignition timing is a mechanical rather than an electrical process, and the firing time must work in harmony with the intake valve, though, like that, it should be regulated by comparison with the position of the piston.

The earlier the spark, so long as pounding does not result, the greater the power of the engine; and the later the spark, the weaker the impulse.

Theoretically, the charge should be fired with the piston exactly at the end of the compression stroke, but it takes an instant of time to fire the whole charge; and unless the spark occurs a little in advance part of the stroke is lost before the expansion of the gases catch up with the piston.

As a rule, when running at 250 R. P. M., the spark should come at about 5/6 or even 3/4 compression stroke. Some fuels fire more promptly though than others, and the amount of compression also in some measure affects the amount of advance which can be allowed. When there is an excess of air in the mixture the power of the engine is increased by advancing the spark, but if gasoline is in excess it is likely to be diminished. Gasoline of high quality burns more promptly than the heavier oils, and the timing should be later. For 65 or 68 degrees Baumé distillate 25 or 30 degrees crankshaft travel below the inward center is not far wrong; but the spark should be adjusted on the fuel used and then the point marked on the fly-wheel. In a two-cylinder four-cycle engine, having located the point for one cylinder, the other mark should be diametrically opposite, while in a four-cycle four-cylinder engine the points would be 90° apart, and the timer driven at one-half engine speed.

146. Irregular Mechanism.—In the make and break system the igniter has a perceptible lag between trip of the sparker and the formation of the spark, and the faster the engine runs the greater number of degrees this lag covers, measured by crank revolution. If all the cylinders were alike this lag would be the same for all, and, once adjusted to one, the others would fall into step. If one of them has a weaker or a stiffer spring the lag may vary in length, and a weaker explosion in one cylinder result.

147. Spark Follies.—To change the governor springs without changing the spark to meet the new condition is wasteful foolishness. If the engine is to be run faster the spark should be advanced.

To start the engine without retarding the spark is still worse. Set for normal conditions, it is far too much advanced for the slow speed of hand cranking, and a pound or back kick is almost a certainty. Aside from great danger of a broken arm, this impulse against the ascending piston is a strain upon bearings, piston, and all of its connections.

Do not run any length of time on retarded spark. Advance it gradually until the full power of the engine is developed, but not enough to pound.

A good place to learn useful lessons on spark timing is behind the exhaust, studying the character of the escaping gases.

CHAPTER VIII.

A CHAPTER ON ENGINE REGULATION.

148. **Controlling an Engine.**—The two distinct phases of engine regulation that require separate treatment as such are speed and temperature control. Of these two the former will be first considered.

149. **The True Mission of the Speed Controller.**—A good many engine operators have gone trouble-hunting around the governor when there was nothing in the world the matter except a mistaken idea of its mission. When an engine operates for any length of time at greater than its normal speed without being automatically checked there is something wrong with the governor. When it drops below normal the governor fails to act because there is nothing for it to do. The fault is in the load, the fuel, or the engine. The governor is intended only to control speed when it attempts to rise above the normal. With the speed, when on account of overload or poor fuel it drops below normal, it has nothing whatever to do, although many people seem to think the governor should keep the speed up to the standard as well as down to it.

Governors are not speed creators. Their sole mission is preventing the speed from rising above a certain standard and, when we change their adjustment, we merely change the standard at which they operate, and not their mission. This idea should be firmly fixed in the mind, as a wrong conception of it has

been the cause of endless confusion with many engine operators.

150. A Few Rules to Remember.—When the engine at normal speed is under full load the governor is unnecessary, and is not in action.

If the load is increased a few pounds the speed may fall a trifle below the normal; still the governor will be unnecessary and inactive.

If the load is decreased a little so that the speed of the engine is inclined to rise above normal, the governor, if in working order, promptly checks the tendency and brings it back to normal; then it ceases to act, and is no longer necessary until the speed attempts to rise again.

In only one of the three conditions cited, the last, is the governor at fault if it remains inactive. In the first there is no fault; in the second, the trouble is with the fuel, or the load is too heavy for the engine, or some part of the latter is out of adjustment. In the last, unless the speed is quickly brought back to normal, the fault is certainly with the governor. It must be remembered, however, that regulating a rise of speed such as may follow the sudden throwing off of a full load requires a moment or two for the governor to adjust itself to its work and regain control.

151. What Changing Governor Adjustment Does.—We may set the governor so as to allow the engine to run below its normal speed; then it will keep it continually below and hold it steady at that speed under variable loads, but the engine will not develop full power.

We may set it for a higher than normal speed in order to increase the power; then the governor will not respond; it has no speed of its own to contribute. If there is no load the engine itself may have suf-

ficient power, when unchecked, to run up to the higher speed the same as a runaway horse or a runaway steam engine might climb up above the normal. This would be due to the released powers of the uncontrolled engine and not to any contribution from the governor. It is the natural inclination of any engine when running light to exhaust its surplus energy in extreme speed. It will do this always unless restrained by a governor or a load that just consumes its entire capacity. Either one is sufficient to control it and one is just as good as the other, while one is quite as helpless as the other to add to the speed from any energy of its own.

152. **Methods of Governing.**—The speed of an over-industrious engine may be moderated in either of three ways: by retarding the spark, by limiting the supply of fuel, and by changing its quality. To accomplish one or more of these we use one of three methods, which we designate as Ignition Control, the Hit-and-Miss system, and the Throttling method. As considerable has already been said with regard to the first in Chapter VII, we will now concern ourselves with the other two methods.

153. **Regulating the Fuel.**—The fuel supply is regulated through the valves. Sometimes the exhaust valve is kept from opening; then the burned gases remain in possession and new fuel cannot enter, so the engine misses fire and loses power impulses until the speed returns to normal and the governor ceases to interfere. Sometimes it is the intake valve that is regulated, either by reducing the volume of vapor admitted and so reducing both the compression and explosion pressure, or by cutting off the gasoline only, and so, without reducing compression, introducing a fuel that will not explode at all; or, if it does, with

greatly diminished energy. In many smaller engines the fuel supply is cut out entirely and the engine's speed responses to this method are quite prompt but rather wasteful.

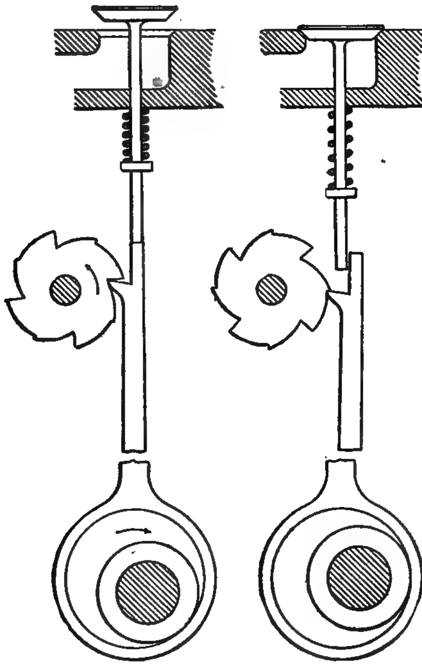


FIG. 43.—Method of Speed Regulation Through Valves.

154. **The Hit-or-Miss System.**—There are a great variety of mechanical devices for making these changes in the fuel, most of which may best be studied direct from the engine. None of them involve any mysterious or new principles. In general, a push rod presses against the valve stem at properly timed intervals and opens it. When the speed increases the engine governor operates some chain of mechanical contrivances

to deflect this push rod from its usual course, so that it does not touch the stem; then the valve remains closed. In a four-cycle engine there is no chance for the governor to change the valve operation oftener than once in two revolutions, so it may require some little interval of time before the speed of an engine, suddenly released of its full load, would be reduced much, and this system, while very economical and reliable, is not suitable for engines intended for driving cream separators, electric generators or any such machinery requiring the maximum of steadiness.

155. **The Throttling Governor.**—Like the hit-or-miss type, the throttling system of government is almost as varied as the different makes of engines. They vary the size of the charge instead of cutting it out entirely, and are considered the best for close regulation.

156. **Types of Governors.**—Either of these forms of speed control may be secured by one of several types of controllers, the most common of which are the centrifugal, the pick blade and inertia governors. Each has its limitations.

157. **The Centrifugal Governor.**—The centrifugal governors all depend upon the principle that a weight revolving rapidly around a center tends to swing out from the center. Two arms, each fitted with a weight at the outer end, are hinged at opposite sides of a shaft to a sleeve which is free to slide upon the shaft. To regulate the results of this tendency to swing out a spring is attached to each weight, tending to hold it toward the center. The mechanism controlling the feed of the engine gets its initial movement from the swinging outward of these weights beyond a certain point. The springs try to restrain the weights within that point, but when the latter are whirled by the speed of the engine up to a certain velocity their tendency

to swing away from the center overcomes the power of the spring and the restraining mechanism; then as the speed decreases the centrifugal pull is reduced so that the springs again overcome it. This type of governor may take the form of two fly-balls, familiar to all as a part of the steam engine; or they may consist of weights in any form and may be attached to the cam shaft, the crank shaft, the fly-wheel or any other rapidly revolving part of the engine. Nearly all farm

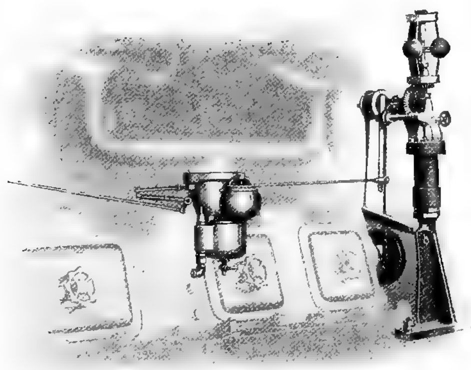


FIG. 44.—Centrifugal Governor Attached to Carburetor.

engines are fitted with some form of governor of this type.

158. **The Pick-Blade Type.**—A swinging or pendulum device, which receives its motion from some moving part of the engine, is attached to a push rod or "pick-blade" which at ordinary speed swings into a notch in a rod or lever operating the valve. When the speed of the engine increases beyond a certain point this blade swings outward too quickly and misses the valve lever; hence the valve remains closed. The operating speed of this type of governor may be

changed by regulating the swing of the pendulum by means of a thumb nut.

159. **Care of the Governor.**—The care of the governor consists mainly in keeping its bearings clean

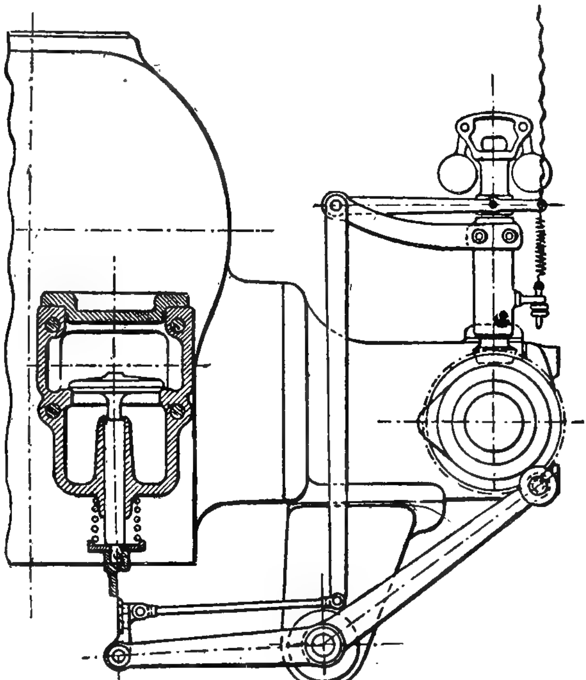


FIG. 45.—Pick-blade Governor, Showing Cam Action.

and supplied with an ample amount of good lubricant without excess. To overcome the tendency of dirt to settle into the oil and gum so that it will not work freely, clean occasionally with kerosene; then apply fresh oil. Changing the governor should be avoided unless for some well defined object. Usually it is set to keep the engine at that speed at which it will do the best all around service, and every change brings

one a little nearer to the time when governor, valve area, and the spark timing will be out of harmonious adjustment.

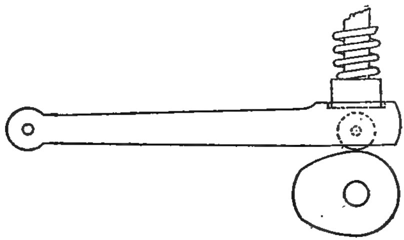


FIG. 46.—Side View of Cam Action on Lever.

160. Governing by Ignition.—Spark control can only be applied within very restricted limits, as all of its possibilities lie between the point where a reverse impulse is fired against the piston and that where the spark is so late that the full volume of the pressure never reaches the piston at all. These limits may be approximated at about 30° of the outward stroke before dead center and perhaps one-fourth as much after. To retard the spark, too, is very wasteful, and it is customary, when this method is used, to unite it with some form of throttling also. In fact, the same results may be obtained with throttling alone and, aside from such special reasons for retarding, as when hand-cranking and starting the engine, it seems preferable to depend upon governing the speed without interfering with the spark.

161. Controlling the Temperature.—Although the internal combustion engine is essentially a heat engine and the conservation of all heat produced would seem to be a matter of fuel economy, there are reasons why it is necessary to introduce a cooling system and destroy a part of our high temperature after we have

obtained it. First of these reasons is the danger of pre-ignition. If the combustion chamber was allowed to remain at the high temperature it attained at the moment of ignition all subsequent charges of fuel would be fired the instant they entered the chamber, before the latter could be filled or the charge compressed. Such extreme temperatures, too, would soon heat the metal too hot to operate and put the piston out of business. For the protection of the lubricants used in the cylinder it is also necessary that the temperature be controlled.

162. **The Usual Systems.**—Practically all farm en-

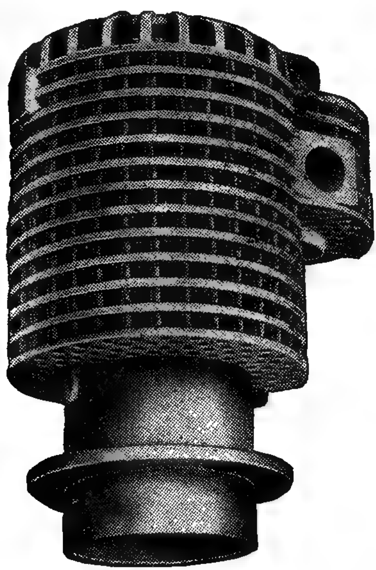


FIG. 47.—Type of Air Cooled Cylinder Used On "New Way" Engines.

gines are cooled by one of two methods: air and water. Oil cooled engines have been built, and some of them

have done good work, but they are not in common use under such conditions as the average farm would have to meet.

163. **The Air Cooled Engine.**—For small size engines air cooling is a favorite method, especially where the engine is not usually run under full load for more than a few hours at a time. Air cooled engines are light and easily moved, a quality that is quite important in the farm motor, especially the small engine, which is used to do the chores and hand work about the barn and house. They are also simpler, have fewer parts and for these reasons are less costly. In cold weather they have a decided advantage; a bit of forgetfulness does not mean a burst water jacket. The extra parts, too, of the water cooled engine all have to be cared for, cleaned occasionally, kept supplied with water, and in correct operation.

164. **The Water-Cooling System.**—For long jobs though, or where the engine has to work under a full load, the water cooled system is the best, especially for heavy engines. Water temperatures are far more stable than air and the danger of overheating and warping some part of the engine, that always confronts with the air cooled system more or less, is entirely absent when water cooling is adopted. Water cooling also has the advantage of keeping a more constant temperature, after it is once regulated. An efficient cooling system, too, will decrease radiation losses and increase working energy, while poor cooling decreases power. The variation from this source alone may be from 15 to 35 per cent. of the heat generated.

165. **The Open Jacket Method.**—Usually the water jacket is a part of the engine casting, the cylinder walls being cast double and the space between filled in with

water. The water, as it heats, boils and evaporates; then of course it has to be renewed. This method has the advantage of using a small amount of water,

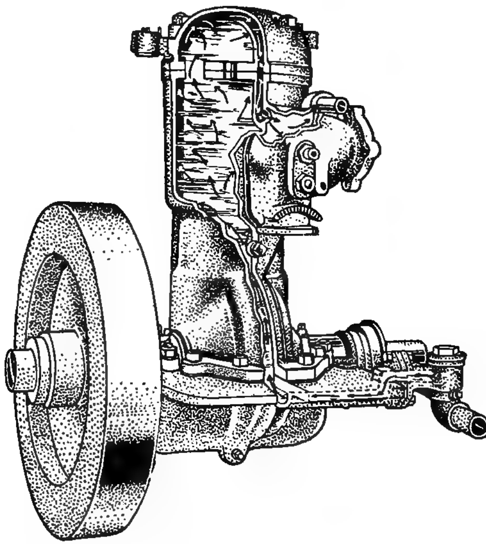


FIG. 48.—Depicting Flow of Water Through Jackets of Water Cooled Engine.

which can be easily replaced; so there is no objection to opening the drain pipe at night and allowing the jacket to empty in freezing weather.

166. **The Circulating System.**—Frequently a tank of greater height than its diameter is located beside the engine, from the bottom of which connection is made with the bottom of the water jacket. A similar connection is made between a point near the top of the jacket and the tank. Once filled, the circulation of the water is automatic, the heated water rising in the jacket and flowing from the upper outlet over to the

tank while the cooler water of the tank is replacing it through the lower connection in the bottom of the jacket. Sometimes a pump is connected with this

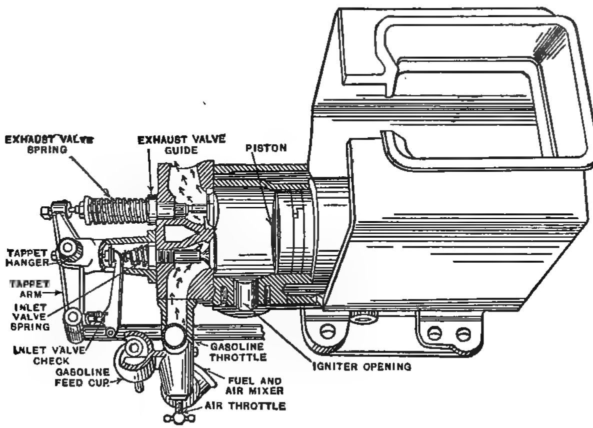


FIG. 49.—Sectional View of Cylinder of I. H. C. Engine, Showing Integrally Cast Hopper Used in Open Jacket Cooling System.

system and the water forced through by positive action of the engine.

167. A Good Circulating Pump System.—One plan now in quite general use in the cooling of small size engines allows the water to fall at the top of an inverted cone and so spread out to the air in a relatively large thin surface as it descends by its own weight. This makes quite an efficient cooler in which comparatively little water is required. With this system, a pump is needed to elevate the water.

168. Other Systems.—While there are a great variety of water-cooling designs upon the market, practically all of them depend upon the action of gravity, of an engine pump, of difference in temperature, or the diversion of some running stream. Of all these

systems the last is the most costly because the more wasteful of heat units. Gravity feed is all right if nothing goes wrong with it, but there is constant danger of some obstruction, the resistance of which it will not have force enough to overcome; so, though it is the more complicated and costly in the beginning, some form of forced circulation is the best.

169. **Amount of Water to Use.**—The least quantity of water that will keep the temperature of the engine down so that the water itself remains only a little below the boiling point is the best quantity to use and, having once determined what this is, the only deviation from it should be such as the difference of conditions might require. An engine working steadily at full load will have a greater tendency to heat than one only partially loaded or that has frequent intervals of rest. As a rule the most efficient results will be obtained with the cooling water somewhere between 190° and 200°, or just a little below the boiling point.

170. **Care of Water System.**—In cold weather the full advantage of an air cooled engine is realized if one ever forgets and allows the water to freeze up. Modern engines are now very generally constructed with a system of cooling which is claimed to be exempt from frost dangers, and to a limited extent this is true. Wherever water is used, however, in cold weather it is a part of the care of an engine to see that the pipes and water connections are in some way secured from danger.

Where the circulating system is used see that the water really circulates, and clean out the sediment occasionally. If the scale is hard use one pint muriatic acid to from four to ten times its volume of water, according to condition of the scale. Be sure and add the

acid to the water, not the water to the acid. Let this mixture remain from 12 to 48 hours, and then flush thoroughly.

171. **Anti-freezing Mixtures.**—These are nearly always injurious to the metal and should not be used except where absolutely necessary, as chemical action of some sort is almost certain to result. Practically all of them depend upon some form of oil, alcohol or salt.

Where the circulating system is not in contact with zinc, aluminum or galvanized iron, 3½ to 4 lbs. calcium chloride to each gallon of water is cheap and effective, but with zinc it starts a destructive action similar to electric battery. The salt sediment is also inclined to settle and make trouble.

Thirty per cent. of glycerine in water will not freeze before 15° above zero is reached, and 55% will stand a temperature of 10° below. This, however, is expensive and contains acid.

One-third alcohol and ⅔ water will stand 15° below zero and is not harmful, but the alcohol will gradually evaporate out.

A mixture of 15 parts alcohol, 15 of glycerine and 70 of water will not freeze above 10° and also raises the boiling point to a higher point. Glycerine is injurious to rubber tubing, though, and any alcohol solution loses its original proportions gradually when exposed to the open air. Where a temperature as low as 15° must be met, as much as 25% alcohol must be used in mixture to render them effective. If below zero, not less than 30% should be used. Wood alcohol has no sediment and does not corrode machinery. Twenty per cent. of wood alcohol and 80% water is suitable for ordinary weather.

When the temperature falls to 40° draw the water

from the jacket, cylinders, pipes and pump. It takes a surprisingly small amount of cold sometimes to burst a pipe or a brass connection. If the tank is in some danger and the refilling of it too much of a task, disconnect the outlet pipe and stop with a cork plug that will blow out under pressure before the tank itself would burst. A few rods let down in the water, but with ends sticking out above the surface, will help a little, the freezing water not infrequently shoving the surface ice upward at the weakened point around the rod, and thereby gaining considerable extra space below to accommodate the expansion.

172. **Utilizing Waste Heat.**—Under average conditions something more than 300 heat units or over 233,400 foot-pounds energy is lost through the discarded heat passed through the exhaust valve for each pound of fuel gas consumed, a loss which somewhat exceeds 7 horse-power per pound of fuel. Various devices have been tried for making use of this wasted energy and some of them have been fairly successful while others have occasioned so much interference with the discharge of the burned gases from the engine that the back pressure and disturbed combustion resulted in a greater additional loss than the gain amounted to. Aside from its use for heating purposes, either to assist the carburetor in cold weather or for other uses, there is probably little chance of turning this lost heat into profitable channels.

A number of successful experiments have been tried out in heating small rooms or even small buildings with this otherwise wasted heat and several special heating devices have been put upon the market. A home made heater of fair efficiency can be made by connecting an ordinary pipe expander by means of a collar coupling with the exhaust of the engine and

extending it by means of a larger pipe up through a tank of water. The larger this pipe the greater will be the heating surface and the less interference there will be with the exhaust blast from the engine. A twenty gallon tank of water can be brought to the boiling point in from 30 to 60 minutes, and by providing for its circulation or by passing a series of air pipes through across the tank and with open ends both the hot water and hot air can be utilized in heating. Care must be taken that there is no leak in the pipe which will allow water to run down into the exhaust and so back to the engine cylinder.

CHAPTER IX.

THE CRANK SHAFT AND ITS BEARINGS.

173. The Engine Frame.—It seems so utterly impossible to construct an engine of any sort without a frame that we are apt to consider its presence forced upon us without any definite use. It has, none the

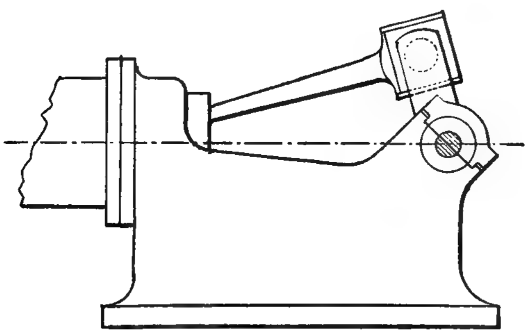


FIG. 50.—Main Bearings Incorrectly Placed. Strain of Explosion Impulse Exerted Directly Against Cap and Bolts.

less, a number of important uses. First, it supports the engine and provides a means of anchoring it securely to any independent foundation we wish to erect. It also holds the various parts of the engine rigid and in correct relation with each other; keeps the crank shaft in line with the piston stroke and its connections, and gives to all a stability that could never be attained unless these various parts were securely tied

together by all being fastened rigidly to this common base.

Gasoline engine frames should be specially strong,

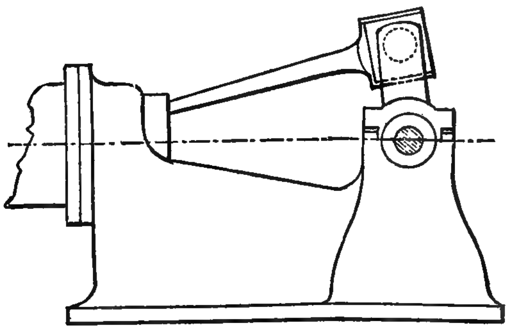


FIG. 51.—Main Bearings Placed so a Twisting Strain Comes On Cap and Bolts Every Impulse.

not only to resist the series of blows or shocks which come to them with each power impulse, but, in the case of large engines, to absorb in their body in some

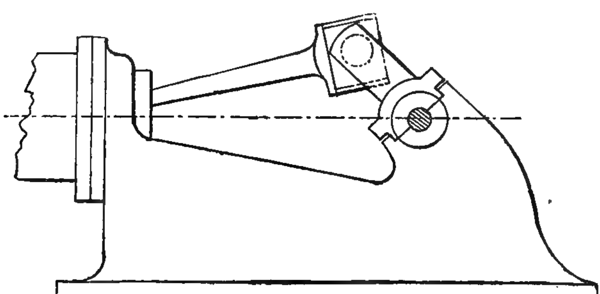


FIG. 52.—Main Bearings Correctly Placed—All Stress Taken by Bed of Engine.

measure the vibration which would otherwise seriously affect the more delicate parts. In the case of horizontal engines the bed design should be such that

the force of the impulse impinges against a portion of the frame provided to receive it rather than against the bolted union between the cap and bed of the main bearings. (See Figs. 50 to 52.) The base plate of a horizontal engine should always be so set that the cylinder is inclined slightly toward the crank shaft in order to drain the lubricating oil away from rather than toward the inner part of the combustion chamber.

174. The Crank Shaft.—The crank shaft has not inappropriately been called the backbone of the en-

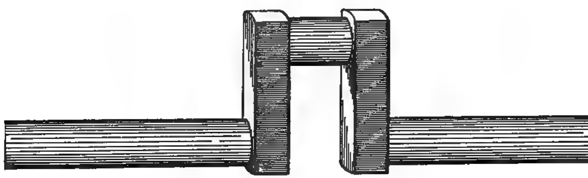


FIG. 53.—Single Throw Crankshaft.

gine. It must receive the full power of the engine, must deliver it to the driven machinery, and must be strong enough to give and to receive the impulse under a twisting strain instead of a straight pull. It should

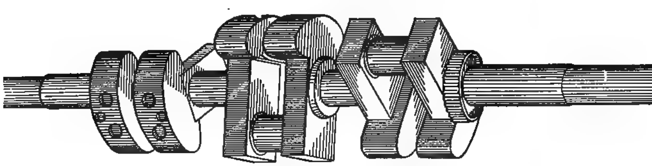


FIG. 54.—Three Throw Crankshaft, With Counterpoise or Balance Weights.

be made of the best mild steel and the crank should be cut out of a mass of metal rather than forged on. The crank-pin should be designed to stand a strain of 400 pounds per square inch of piston area, and the

diameter of the shaft in the main bearings should be about 1.25 times the diameter of the crank-pin. The length of the main bearings should be from 1.75 to 2 times the diameter of the shaft, and the length of the projection depends upon whether the belt wheel is bolted to the fly wheel or keyed to the shaft. If the latter, which is preferable, the shaft should be only long enough to engage the full hub of the pulley; then there will be no temptation to the operator to set the wheel out from the gearing and so increase the twisting stress on the shaft.

In order to make the shaft run more smoothly weights are fastened to the crank, to compensate for its weight beyond the center of shaft revolution.

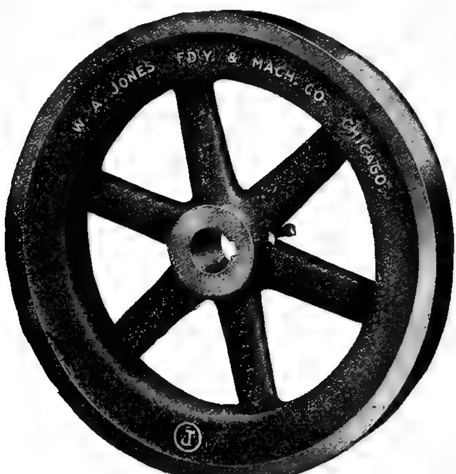


FIG. 55.—Gas Engine Flywheel of Approved Design.

175. **Fly Wheels and Their Mission.**—It is the mission of the fly wheel to correct any unevenness of speed arising from the intermittent powers of the gasoline engine or from varying crank positions by stor-

ing up excessive bursts of energy and then giving it out again when the speed tends to fall below normal. In one sense they act as a governor, but they do more in that they also store energy.

176. Heavy Fly Wheels Needed.—The heavier the rim of the fly wheel, the greater is its capacity for equalizing the variable speeds. The energy given by a gasoline engine fluctuates rapidly from its full maximum power to the point where, during the compression stroke, energy is being consumed instead of given

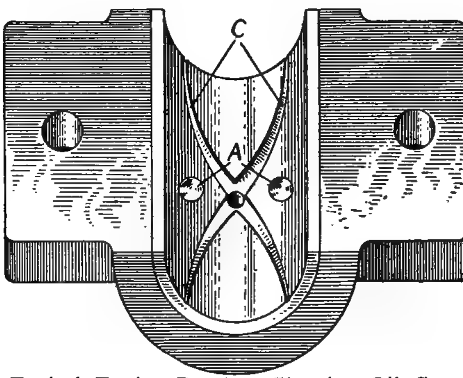


FIG. 56.—Typical Engine Bearing, Showing Oil Grooves C and Retaining Plugs A.

out. It is necessary that the fly wheel rim be heavy enough to absorb all excess energy given out at the instant of the power impulse and then without any sudden change of velocity, give enough of it back to carry the engine over the compression stroke. Centrifugal energy, however, inclines the swiftly moving rim to leave its curved path around a center and take up a straight one tangent to it; and this tendency is stronger in a heavy wheel than in a lighter one revolving at equal speed. For this reason the point is

soon reached when it is not safe to further increase the weight of the wheel unless we reduce its velocity, so, in order to provide power necessary to carry the engine past its compression stroke, we divide the weight and the strain between two wheels and place one at each end of the shaft, where there will be the least unbalancing and twisting of the shaft. That is why so many modern gasoline engines have two fly wheels. There are, however, several distinct advantages in a single wheel of greater weight, of which these are perhaps the most important:

A single wheel leaves one side of the engine more accessible.

Any variation in the inertia between the two wheels sets up a serious twisting strain upon the shaft.

With the one wheel a third bearing has to be provided and the single wheel is supported on each side. This is usually provided though only with large, expensive engines, and of the small power engines of moderate or low price nearly all have the two wheel system.

At about 250 revolutions per minute engines of ordinary farm size require fly wheel weight of about 100 pounds per horse-power of engine, the weight being divided between the two wheels. Hit-and-miss governed engines require somewhat heavier fly wheels than throttled, while an engine used upon a variable load can use to advantage greater weight than one inclined of itself to run with a steadier motion. Four-cycle engines require heavier fly wheels than two-cycle, because the power impulse only comes at every second revolution.

Fly wheels are made with both straight and curved spokes. When the latter, they should invariably be put on the shaft so they will revolve with the advance

part of the spoke next the rim. A safe rim speed for cast iron wheels of approved pattern is put at about 5,000 feet per minute. The hub should be 2½ to 3 times the diameter of the shaft.

It is highly important that the fly wheel be properly centered and balanced on its shaft. A small amount of wabbling increases immensely the strain upon the rim and may be the means of wrecking the wheel. See to it occasionally that the key has not become loosened enough to allow of any independent motion or that the bearings have not been worn until the shaft is out of true.

Never remove a fly wheel from the shaft if possible to avoid it. As it comes from the factory, a fly wheel seldom works loose, but, once removed, it is sometimes almost impossible to secure it safely again. A loose fly wheel is a very serious matter as it will almost invariably, on a high speed engine, break the crank shaft or else wreck the engine, while it is one of the most difficult troubles of all to locate on account of its habit of imitating to perfection the knock which is associated with other causes. Often it mimics pre-ignition admirably; while other familiar sounds, such as produced by loose bearings, are produced. Occasionally the wheel has to be removed in repairing or replacing a broken part, as a crank shaft, but, fortunately, the occasion is of rare occurrence.

177. **The Main Bearings.**—The smooth operation of the crank shaft depends in a great measure upon the bearings, their construction, condition and care. Bearings should be long and heavy enough to insure complete support under the heaviest load without strain. Their alignment must be perfect. They should neither be too loose nor too tight and should

be an accurate circle. The lining, too, should be of suitable material, and this includes the lubrication, as well as the permanent lining.

178. **The Best Lining.**—There is a good deal of difference of opinion as to what material should be used for babbitting the boxes. The softer alloys, as true babbitt metal, have the advantage of being first to suffer in case of lubrication failure. The babbitt is simply melted out instead of a crank shaft being ruined. They have the fault of not only being too soft to wear well; under heavy loads they tend to break down and spread, though under moderate loads their very pliancy sometimes keeps them best fitted close to a shaft that may have been wearing out of form.

Phosphor bronze, on the other hand, will stand up under almost any load and seems almost unwearable; but should lubrication be forgotten it begins to cut the shaft at once and may quite ruin it before the failure has been noticed. Some of the hard alloys are liable to crack and if their surface is not perfect the high and low spots wear unevenly and establish a decided tendency to cut.

Linings made of alloys often develop a tendency to separate into the original metals, either on account of careless mixing, too much heat, or too rapid cooling. Sometimes there is a tendency to crystallize into coarse grains which are brittle and worthless for bearings.

Lead is perhaps the best wear-resisting metal known, but it is too soft to stand the pressure. Mixed with antimony, the resulting alloy stands up better under pressure, loses some of its wear-resisting qualities, but, on the whole, is quite satisfactory under certain conditions. An alloy made up of but two sub-

stances, however, lacks in pliability; hence, three or more are generally preferred.

In lining the boxes for heavy usage one important difference should always be remembered between the so-called white alloys and the bronzes, which contain copper. If a bronze is used there is a tendency on the part of the copper to cling to the revolving shaft and roughen it. This of course increases friction. The white alloys begin to melt instead, and the softened metal acts as a lubricant, reducing the friction and protecting the shaft, though at the expense of the lining.

179. **Why Bearings Heat.**—Heating may be caused by insufficient or poor lubricants, or by being too tight or too loose, or by the shaft or bearing being out of true. There cannot be a fit unless the journals are true cylinders, and there is a tendency with gasoline engines to flatten at the points of highest pressure.

In the latter case the bearings must be trued up by grinding; the shaft by grinding or filing; and this is not a job for the careless or the amateur. It needs the machinist's accuracy. As a rule the novice had better let all interference with the shape of the bearings strictly alone and should content himself with doing what can be done by means of oil. The treatment of hot boxes, also babbitting, will be treated fully in another chapter.

180. **Gear Wheels.**—On almost all makes of gasoline engines will be noticed various small gear wheels, cams, push levers and connecting rods. Most of these belong to the valve, ignition, and governing systems, and are set to mesh accurately with regard to each other and the main shaft. To change the set of any of them is to court trouble unless the exact purpose

of the wheel is fully understood and the change is made to correct a previous fault. If for any reason one has occasion to remove any of these wheels from the shaft he should under no circumstances fail to first mark the tooth of a wheel and the depression into which it meshes with its mate. Most engines are so marked when they come from the factory; but some are not, and no one can afford to take any chances without positively knowing that the marks are already there.

To attempt describing all of these trimmings in detail would be to make it necessary to describe about every make of engine on the market. By keeping in mind the general principles already given, a little study of the engine itself will soon disclose the purpose of each and how it is attained.

181. **Care of These Minor Parts.**—They are under no strain but that of the usual friction. All the attention they require as a rule is enough oil to keep them always easy to operate, and free from gum and dirt. For the slides an occasional dressing of graphite is of benefit. Occasionally a washing off with kerosene or turpentine will relieve of gum, and a dressing of graphite now and then for the gear wheel teeth renders them smoother and causes them to mesh with less friction.

182. **Casual Acquaintances.**—Almost every engine outfit, after it has been in use for a few years, has fittings of its own which represent the needs, wisdom or whim of the owner. Self-starters are becoming more and more common and, while they are not very much needed for engines less than 4 or 5 H. P., and are by no means a necessity, even for a considerably heavier rating, they are, of course, always a conve-

nience, providing they are not too complicated and costly.

Gasoline pumps are taking the place of gravity feed with stationary and even portable engines. The gasoline is pumped up from a tank in the base of the engine or from a stationary tank below in such quantity that there is a constant excess delivered to the carburetor; then a return pipe is provided for taking the overflow back to the tank. This insures that the level in the carburetor remains always constant and there is no possibility of engine variations due to fluctuating supply of fuel.

When purchasing or considering any uncommon attachment one should first consider well what it is for; whether it was created just to sell or if it really fills a place that needs to be filled. If the latter, it is wise to next consider whether the work it will do is of enough importance to warrant the extra expense, the extra care and attention and, most important of all, whether it is something that may interfere with the working of the engine, either by obstructing the air intake or the exhaust or any other part of the system that the manufacturers installed, and that, left alone, is doing satisfactory service.

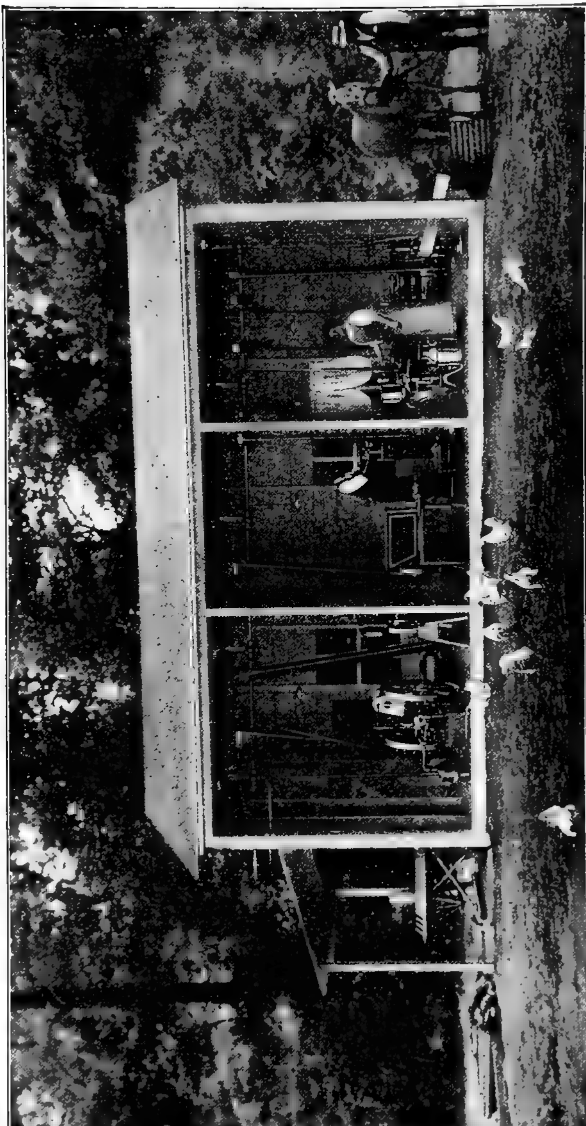


FIG. 57.—The New Farm Factory Made Possible by Modern Gasoline Engine. Note Wood Saw at One End and Watering Trough at the Other.

CHAPTER X.

SETTING THE ENGINE.

183. **Proper Setting Important.**—Gasoline engines are practically automatic when properly installed. Under less favorable conditions they are only partially so; hence, it is important to give them the best surroundings possible.

184. **Stationary Foundations.**—Stationary foundations are the most constant in their requirements. They also afford the best chance for meeting the requirements, and include so many of the ideal conditions which all foundations should aim to include, that they should have our closest study.

185. **The Four-fold Object of a Good Foundation.**—The several purposes of the foundation are to support the weight of the engine, to maintain it at a fixed position in relation to its work, to protect it from outside vibration, as of other moving machinery, and to absorb a certain amount of the vibration of the engine. A stiff, solid clay bed probably serves this four-fold purpose better than any other common substance, as it is firm enough to do the work and at the same time contains enough elasticity to retard the dreaded crystallization which always sets up more or less in metals whenever an irresistible force is made to batter persistently against a rigid object.

186. **Depth and Nature of Foundation.**—Surface clay, however, is subject to its own disturbances, so the foundation should be carried well below the surface

by a wall of stone or brick or concrete, the depth depending a great deal upon the size of the engine and the nature of the ground. Ordinarily a depth of three feet will be ample for engines of six H. P. or less; 4 feet for up to twelve H. P. and five feet for as heavy an engine as twenty-five horse-power, or as large a stationary engine as a farm ever needs.

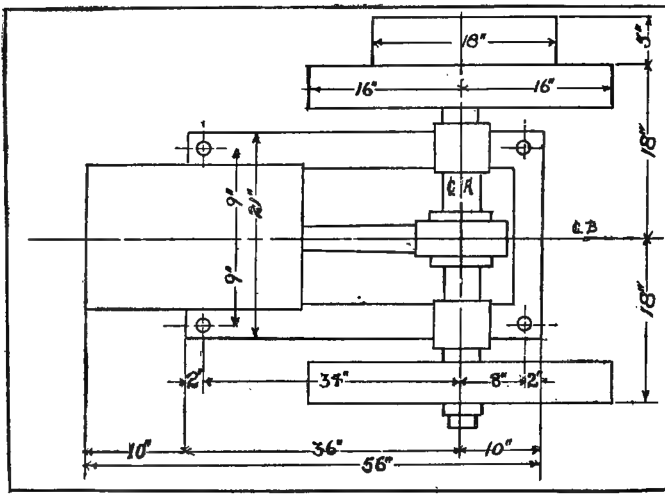


FIG. 58.—Gasoline Engine Base Plan to Show Amount of Space and Holes Needed for Installation.

187. The Foundation Blue Print.—Every stationary engine sale should include a foundation blue print prepared at the factory. The lines of this are nearly always measured off from two base lines, one of which follows the center of the crank shaft and the other represents the center lines of the crank shaft and cylinder. In a horizontal engine these lines are at right angles to each other and parallel to the plane of the foundation.

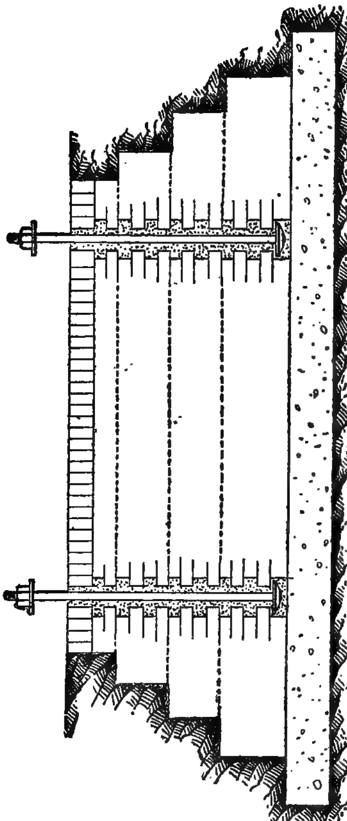


FIG. 59.—Method of Securing Heavy Engine to Concrete Foundation.

188. Tying Engine to Foundation.—The operative strength of the best foundation is only as great in relation to the engine as that of the ties which bind them together. But it is occasionally necessary to loosen an engine from its foundation, and the fastenings must be such as may be released with the least amount of labor, while at the same time making it possible to secure the engine as firmly as possible whenever that is desired. This double consideration is usually attained by means of long bolts set in the concrete and extending through the engine bed and almost through the entire concrete foundation, of which they are virtually a part.

189. Material Needed for Foundation.—In addition to the sand, gravel and cement needed for filling the foundation pit, the work requires as many long bolt rods as there are bolt holes in the bed of the engine, two heavy cast washers for each bolt, with nuts; a length of gas pipe for each bolt, and a quantity of inch boards for the templet.

190. Preparing Material.—Let us suppose we are to put in a three-foot foundation for a small engine. Each bolt should be just long enough to reach through the engine bed, two cast washers of suitable size, and two nuts (if the bolt is merely a rod threaded at each end and without head, three nuts will be required), besides all but a few inches of the concrete foundation. As it is hard to get such long bolts, a good way is to obtain an iron rod of proper size to fit the bolt holes, have it cut into lengths by a blacksmith, one end threaded for nut and two or three inches of the other end turned sharply at right angles for a head.

For each bolt provide a gas pipe covering, the inside diameter of which is at least one-half inch larger

than the bolt. These pipes should reach from the head of the bolt (or the washer at the head, if one is used), to the surface of the concrete only.

191. **Making the Templet.**—The foundation templet is usually made of one-inch boards, and in the form of a rectangular parallelogram, about four inches wider and longer than the size of the engine bed. This represents the surface of the completed foundation and provides for a two-inch projection all around beyond the iron frame. Lay off on this the line AB (see Fig.

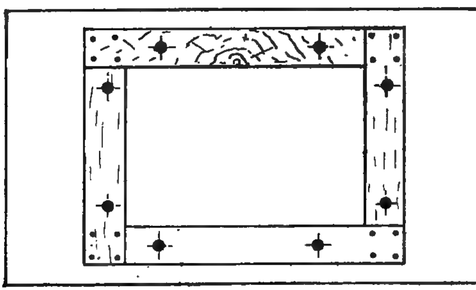


FIG. 60.—Templet for Locating Bolt Holes.

58), along the center, corresponding with the center of the engine cylinder as on the blue print. Measure off on this line from each end the distance between bolt hole and end in blue print, then add the two-inch allowance for projection. That is, if the bolt holes are four inches from the end in the blue print lay them off six inches from the end of the templet, measuring along the line AB; and at these points on that line draw lines at right angles to the AB or base line. Locate bolt holes on these lines and bore holes in templet a trifle larger than the bolts. Slip washer down to head of bolt, then put on length of pipe, insert threaded end through templet from under side,

put on upper washer and nut and draw templet tight between nut and shoulder made by pipe.

192. **Making a Frame.**—The frame of small engines is usually thick enough to raise the fly wheel clear of the floor, but it is best to build the concrete foundation a few inches above the surface and, in order to have this form square, a frame is necessary. Some 2 by 4-inch stuff is about right, the two side pieces being somewhat longer than the foundation for convenience in lifting. The top of this frame will be on an exact level with the top of the foundation and upon it we will lay the templet, the bolts extending downward into the pit below. The frame must then be shifted until square with the lines on the templet, the latter, of course, being placed to exactly conform with the position to be occupied by the engine.

193. **Filling the Pit.**—Having fastened the frame in place by means of stakes, remove the templet and fill the pit up about a foot with concrete made from about seven parts of clean sharp gravel (crushed stone is better) to one of good cement. Tamp this firmly and then replace templet, squaring the lines carefully again with shafting, sides of building or any other lines in relation to which the engine should be square; also see that the frame has not been moved. Fasten templet on frame and continue filling, tamping down as needed. When near the top change proportion of concrete to about five to one. Continue this until within three or four inches from top of frame; then remove nuts and washers and lift off templet, being careful not to disturb the pipes encasing the bolts. Fill to the top of frame with clean sand and cement in about the proportion of two to one. The foundation should now be left to harden thoroughly.

194. **Placing the Engine.**—To set a heavy engine

upon a fresh cement foundation, without doing mischief, requires care. Raise engine upon blocks at one end of foundation and about six inches above it, the block being topped by two planks long enough to include both the engine and the foundation. Holes or notches may have to be made in these planks to avoid the bolt ends. Slip small rollers under engine, across the plank, and work the engine slowly over its place on the foundation. Keep blocking in front of the rollers constantly to prevent any possibility of the engine getting away. As one roller comes to a bolt end, slip another in ahead of the bolt and remove the first.

195. **The Final Setting.**—When the engine is approximately in position, lower gradually until the bolts are all engaged in their respective holes in the engine frame, then the engine should be carefully lined up with any shafting which it is expected to work to when set. The use of the pipes around bolts will now be appreciated, as they give far greater latitude in this shifting or in correcting slight errors than could possibly be had with bolts set rigidly in concrete.

196. **Locking the Bolts in Place.**—When the engine is finally placed, flow a mixture of water and pure cement into each pipe until it is full, then, without shifting it, lower engine upon the concrete, give the lines a final test and leave the engine undisturbed for a couple of days until the cement hardens in the pipes around the bolts. The result will be a job that is permanent, and as perfect, mechanically, as the skill and care of the workman have seen fit to produce.

197. **Lining Up.**—Mention has been made of lining up with a line shaft. Where the engine is installed in some building in which machinery has been previously run this may be necessary, though it is usually best to set the engine first and then line the shafting to

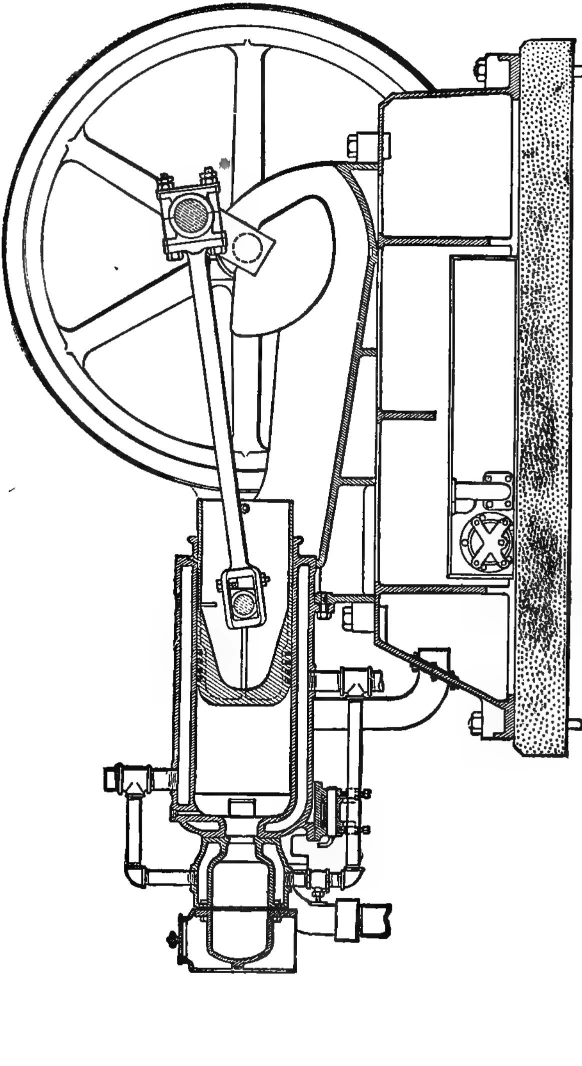


Fig. 61.—Engine on Foundation, Bolted in Place.

it. To the amateur lining to a shaft may prove a little difficult. Two methods are in common use, the overhead and the floor method. In the former, a straightedge is tacked lightly over the shaft and from one edge, at a distance of six or eight feet from each other, two plumb bobs are suspended. The straightedge is then shifted until each of these lines clears the side of the shaft in passing it by exactly the same distance, say one inch. Never undertake to drop the lines so they will be in contact with the shaft, as one or the other is almost certain to be slightly deflected by the contact to some extent—just how much is all guesswork.

Slide the engine into approximately its correct position; remove plumb bobs from first straightedge and fasten them to a second located above the crank shaft of the engine. Measure off on the ceiling equal distances between the ends of these two straightedges; then shift engine until the two plumb bobs clear crank shaft by the same amount. If the work has been accurately done the crank shaft will be exactly parallel with the line shaft. If the plumb lines trouble by swaying in the wind, let the bobs swing into pails of water. This steadies them and at the same time does not interfere with their taking their proper positions.

198. Leveling the Engine.—This would not be difficult if the top of the foundation was made perfectly level and no variation in the engine frame, but neither of these conditions may be absolutely true.

It is the crank shaft always that must be level; the rest of the engine has been built to that. In the engine's longitudinal direction, the setting is of less importance, the preference being that the combustion end of the cylinder in a horizontal engine be a trifle the

highest in order to incline the lubricating oils toward the other end. If there is room to use a level on the crank shaft the work is simple, but there is not always room. In such cases it is sometimes necessary to take readings from the level applied to the rim of the fly wheel turned in different positions. If all correspond, the face of the wheel is true, and, by bringing it to a correct vertical line, the shaft will be level, the engine being held in position by means of thin wedges inserted before the nuts are fully tightened.

199. Other Foundations and Their Failings.—Many less substantial foundations are in use, and giving fair

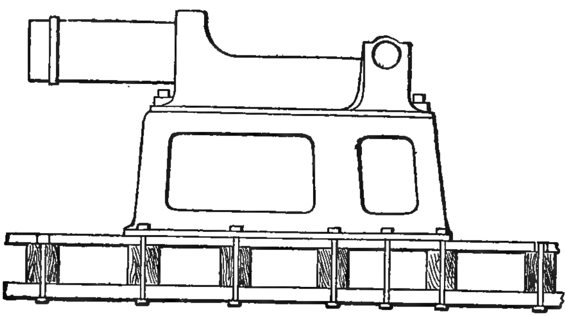


FIG. 62.—Method of Reinforcing Wooden Floors.

to excellent satisfaction. Wooden timbers are often used, so are iron girders, reinforced wooden floors, even the earth, scraped smooth. Vibration troubles are almost sure to develop some time when an engine is set directly upon a floor of ordinary strength. Girders are rather expensive for small engines and too rigid for large ones, the crystallization danger being introduced. Direct earth foundations are unexcelled as vibration absorbers but are apt to collect too much dampness for the good of the machinery, besides being

subject to changes from frost and other causes that throw the machinery out of line.

200. A Unique Foundation.—Perhaps the simplest and most unusual foundation is the so-called vacuum or sheet rubber foundation, in which a thick sheet of rubber is spread upon the bare ground or floor. The pressure from the weight of the engine, it is claimed, binds this to the engine and the ground as firmly as bolts would and at the same time deadens the vibration and reduces the running strain to the minimum. These foundations are still to be regarded as an experiment and not many of them are yet in use.

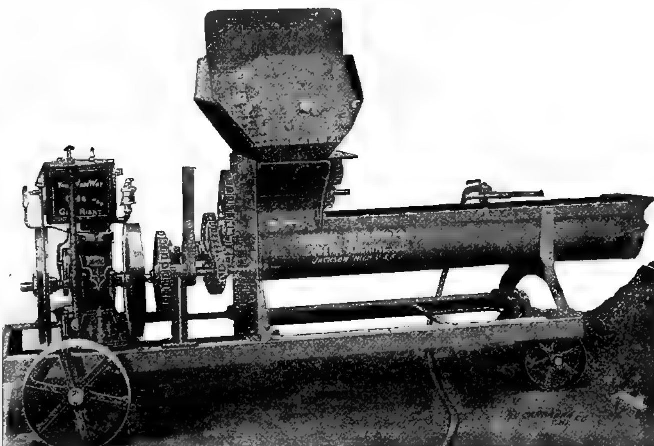


FIG. 63.—A Gasoline Engine Driven Concrete Mixer.

201. Portable Foundations.—Portable foundations are never as satisfactory as stationary, because they are not as secure. Only the small engine requires them usually, and the strain is not great enough to be exacting. Many of the smaller sizes are bolted to light sills with handles at each end and may be picked up and

carried by two men. When running, they should be secured with floor hooks or by some form of staking down. Even wheelbarrow foundations are on the market; then there are light engines designed for using on a binder and for such auxiliary work, that may be fastened almost anywhere by means of hooks or bolts or some special form of frame. For the larger sizes sills are often provided, each end of which is shaped like a sled-runner; then it is little trouble to hitch a horse to either end and move the engine about at will.

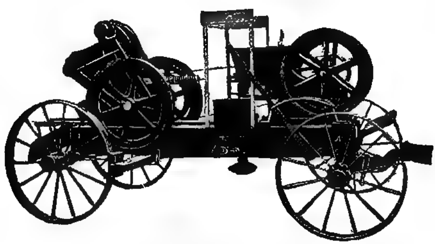


FIG. 64.—A Gasoline Engine Driven Stone Crusher.

202. Mounted Engines.—Mounted engines of course add to the convenience of moving the engine about, as they also add to both the cost and the vibration. No stationary engine should be purchased for this style of mounting without first finding out whether it is available for such a purpose. Some engines would produce so much vibration that half of their power would be destroyed. Others may be set without other support upon an empty barrel, without any display of unsteadiness.

Where the engine is mounted on wheels, braces should be hinged at each end of the trucks and forced into place while the engine is running empty. If the coupling is long the sills should be very heavy or a

jack-screw set under a cross-piece near the middle. Often the power of the engine will be increased at least a third by jacking up and making a vibrating

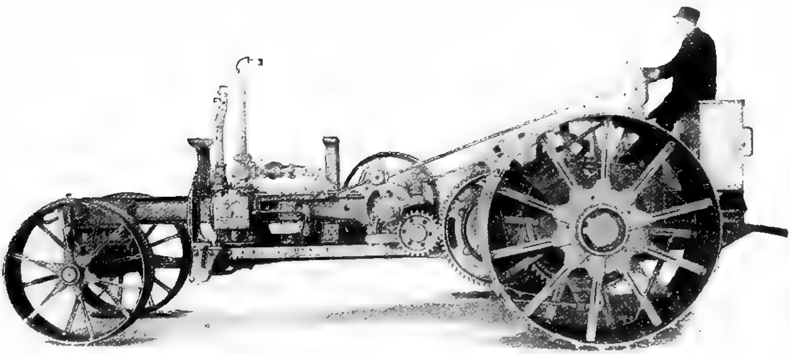


FIG. 65.—A Wheeled Foundation Needed for Tractor Engine.

foundation more rigid. For tractor foundations see chapters on the traction engine.

203. **Shelter.**—There is nothing about a gasoline engine except the ignition system that requires greater protection from the weather than a steam engine ought to have. Shelter pays with any engine and, where water is allowed free access to the ignition system of the gasoline engine, short-circuiting is almost sure to follow. The batteries must be kept dry. Water in the coil or spark plug may short-circuit quite as thoroughly as a misplaced wire. Outside wires are supposed to be comparatively water-proof; but so is a safe fire-proof; if the fire is not too hot and long continued. The elements will break through any ordinary protection in the course of time, and the water-proofing about the average engine is provided against emergencies, and not for continuous service.

Any engine, stationary, portable, or tractor, deserves shelter and will pay for it in extra service. Nothing elaborate is required; just something that will turn wind and water; still, the double walls and dead air spaces of cement block structures present arguments of economy if the engine is to be used much in cold weather. Once started, it will furnish its own heat, but not always wholly from waste heat, or at least some of that spent in regulating temperature might otherwise have been used in creating power. Besides, a farm can make use of the waste heat usually in cold weather, if the operator is ingenious.

Whatever kind of enclosure is used, it should be something that will exclude dust, and it should be kept clean within. Dust may do as much harm to the gasoline engine through the intake pipe as bad air can to the human lungs. Air taken from an elevation is best, away from the gases of the workshop and the stables; but the pipe must be of ample size to insure against excessive friction. The power of the engine can be almost destroyed by limiting the supply of good, pure air. A long pipe no larger than the intake or one with many turns is almost certain to give trouble.

204. **Fittings of the Engine Room.**—There is more danger of having too many tools and supplies in the engine room than of not having enough, but no room can be kept in order unless there is special provision for all that has to be kept there. Every engine room should be provided with closed shelves or cupboards, and a few drawers. Devote one shelf entirely to the various wrenches needed about the engine, and then regard every wrench found out of its regular place, when not in use, as so much misplaced matter that should be set back where it belongs. Another

shelf may contain hammer, punch, cold chisels, files, etc. This should be locked and the key mislaid in order to give time for a second thought before applying any of these harsher tools to the engine. A shelfful of supplies will be needed for the ignition system; wire pliers, an ammeter, some insulated wire, a coil of No. 10 or 12 bare copper wire, a pair of rubber gloves or overshoes, and an extra cell or two for the battery. Most engines are sent out with an extra spark plug. Keep this and all other electrical supplies on its own shelf, and NOT in the battery box.

Frame the directions sent out by the factory with the engine and hang on the wall under glass, or else with a treatment of spar varnish; then do not be too proud to consult them when in doubt. The man who made the engine knows some things about it that it is no disgrace for the man who runs it to have to learn. A drawer should also be given to all the printed price-lists of parts, or any other literature pertaining to the engine. Even the selling claims may help determine what may reasonably be required of it. Don't be afraid to consult the engine company's literature, and to study it frequently.

205. **Storing Oil in the Engine Room.**—One compartment which should be kept closed from the engine room excepting when in actual use, and ventilated from outside, should be lined with sheet iron, tin or zinc. An oil-tight tray at the bottom should be provided to catch any drip and to prevent disagreeable oily bottoms on jugs and cans, a sheet of corrugated roofing, with liberal perforations, may be fitted in just above the tray. In this compartment should be stored a large can or barrel of the best gasoline-engine cylinder oil, and fitted near the bottom with a faucet and a funnel that is small enough to con-

duct oil directly into the oiling can; a similar can of good lubricating oil, for the bearings, a pot of best tested grease, and one of graphite; also, a small can of kerosene, and of gasoline for cleaning purposes. Keep this compartment as clean as possible, but remember that it is not possible to keep it as clean as the rest of the premises should be. A box of drawers for waste should be close at hand, with a separate metal-lined tight drawer, for partly used waste and oily cloths. This should be small, so there will not be room for any great accumulation and it should be strictly fire-proof against any fire likely to occur in its own contents.

206. **The Work Bench.**—A small work bench and vise are convenient, but nothing elaborate enough to attract general farm repair work to the engine room. A limited supply of nails, bolts, and rivets in drawers is advisable, also a rack for a few lengths of water and gas pipe, with drawers below for the couplings.

207. **The Engine Room Floor.**—For the stationary engine a cement or wooden floor is better than earth, because it can be scrubbed out when necessary. Where a tractor is housed, grade up enough to insure complete surface drainage, and use gravel or plank for the run-way. A large door at both sides is a great convenience. If a plank floor is used, a pit for standing while at work under the tractor is a great convenience though not absolutely necessary, as a farm tractor does not run close to the ground like a locomotive.

208. **Ventilation.**—Ventilation is of great importance in the farm engine house, even though the air supply for the engine is drawn from outside. There is always the possibility of a gasoline leak, and an air-tight building is a constant invitation to disaster.

Window ventilation should be provided, but is not enough. A three-foot surface of grating should be let into the two opposite sides of the room and these left open constantly when the room is not in use. During the severest weather, when the personal comfort of the operator requires it, they may be closed with hinged shutters inside. As the pump from the main gasoline supply tank should be located in this room, any leak which ever occurs in the system is pretty certain to find an outlet in this room. Because of this, as well as to prevent tampering with the engine, it is safest to keep the engine room locked when the operator is not there.

209. **The Engine Room Lineshaft.**—Where a stationary engine and a tractor are both used, it is a good plan to run a lineshaft through the engine room, to which the tractor, when not in use elsewhere, can be belted. During the winter months, when much of the inside engine work of the heavier sort will be needed, one can then have plenty of power and at the same time have the advantages which the small engine for some purposes offers over a large one. Care must be taken in belting two engines to one shaft that the proportion between the driver and the driven wheels be figured out correctly, so that both engines will be driving the shaft at the same number of revolutions per minute; otherwise there will be a good deal of lost energy and unnecessary strain of belt and machinery. If the two engines can be located near opposite ends of the shaft a good deal of torsion strain is saved. A better plan is to use a loose pulley next to each driving member and run the belt from either small engine or tractor free, driving from only one engine.

210. **The Mission of Paint.**—This is not different

from its mission around all kinds of farm machinery which is exposed to hard weather or usage conditions. In general, paint is intended to protect the surface to which it is applied from atmospheric chemical action; but it has been discovered that electrical action may be even more destructive, and in the painting of metals it is highly important to take this into consideration. One of the very best paints for protecting iron from rust is red lead, but to use it is to turn a small electric battery at work, tearing the iron to pieces wherever a porous place or a crack admits the atmosphere and moisture. Theoretically, a good oil varnish is the best possible covering for iron, if the iron is absolutely clean when painted. The varnish will not adhere to rusty, greasy, or wet iron, and its contraction while drying opens up minute cracks over the imperfectly coated spots and the work of destruction will continue unsuspected under the painted surface. In order to render the iron entirely waterproof, the varnish must be absolutely dry before exposure to the weather.

Iron can be cleaned of the grease and gum with which an engine is so frequently coated by thoroughly covering with turpentine for a few hours, floating the liquid on freely and frequently until the gum breaks down. Kerosene and gasoline are sometimes used for this purpose, but turpentine is better. Concentrated lye will sometimes succeed where other methods have failed, as it unites with the grease to form soap, and that is easily removed. The lye must afterwards be cleaned off very thoroughly before painting.

211. **Painting the Muffler.**—For painting the muffler or pipes that are subject to severe heat, mix equal parts by weight of Japan varnish and boiled linseed oil. For each half-pound of this mixture add slowly and

in succession, while stirring briskly, one and one-half ounces of lamp black, the same of pure powdered graphite, and three-eighths of an ounce of powdered oxide of manganese. Thin down with turpentine, and paint at once. As this paint dries very fast, the muffler must be cleaned before the paint is mixed. Stir constantly while painting, and apply while the muffler is hot.

212. **Engine Room Abominations.**—The loafer is always an abomination and especially when around machinery. Power producing plants seem to be specially attractive to this class of people who appear to have so little business of their own, and the boiler or engine room of many a factory has ever been the favorite loafing place of the chronic story-teller. Avoid him by making no provision for his entertainment. The engine room is a place for business only. Chairs, boxes, benches are all out of place there. There is no necessity for the operator to remain standing longer at a time than his feet will sustain him and no one else has any business there; not as a long time fixture.

213. **And a Few Cautions.**—Nor is the chronic loafer the only one who likes to hang around engines. Often it is young boys, who seem to take to them by nature and who frequently, if the occasion presents, sometimes through mischief, but more through misdirected curiosity and overconfidence, subject the engine to so many readjustments that the owner learns many new things in engine management before he is ever able to start up again. The spirit of mechanical investigation ought to be encouraged in the boys but they should also be impressed with the fact that all engine management must be under certain fixed rules and that only those who are first familiar with the

rules know how to apply them. There is only one way for anyone to make this impression a fixed certainty, by knowing when people not connected with the farm are around the engine, who they are and what they are doing; that is by taking the same precautions which circumstances would make necessary in protecting a new horse or any other attractive purchase.

214. **Eliminating the Danger Risk.**—The rapidly revolving flywheel of the average engine when used in exposed places introduces an element of danger to the onlooker that should be carefully guarded against by making a light frame of iron pipe or wood members to enclose the revolving member. If this has walls of poultry wire to enclose the mechanism, this precaution will prevent any projecting ends of clothing from becoming caught in the flywheel. The hot exhaust pipe, too, is often a source of menace and should be covered with asbestos lagging to prevent inopportune burns.

CHAPTER XI.

THE FUEL SUPPLY.

215. **Gasoline, and Its Nature.**—Perhaps more people are killed or injured annually by gasoline through ignorance of its true character than by any other industrial agent; yet, properly handled, it is no more dangerous than water. At 40° a lighted match thrown on its surface would be extinguished. At 90° it might be; it certainly would be in liquid gasoline or pure gasoline vapor.

216. **Its True Value and Danger.**—Liquid gasoline will not ignite from flame at ordinary temperatures, but far less heat than that from a burning match will, if favorably placed, be enough to convert it rapidly into a gas which, mixed with the oxygen of the air, is very highly inflammable. This tendency to vaporize so readily, in fact at any temperature a few degrees above freezing, is what makes gasoline so readily available for engine use. As more heat is applied, the vaporizing becomes more rapid. An open dish of gasoline in the sunlight where a brisk current of warm air passes over it will evaporate so rapidly as to present the appearance of boiling. So the current of air passing over its surface in the carburetor carries a mixture of the readily formed gas along with it into the engine cylinder.

217. **Pure Gasoline Vapor Non-inflammable.**—By itself, gasoline vapor will not ignite; it requires the presence of oxygen, which it gets from the air. About

one part of vapor to eight of air makes the ideal mixture for thorough combustion theoretically, though, on account of atmospheric impurities, one part to twelve of air is more nearly the proportion in actual practice. Only a little variation either way destroys the combustible properties of the mixture.

218. **How Gasoline Is Obtained.**—Gasoline is one of the most volatile products from crude petroleum, coming over as one of the first by-products in the process of distillation. It was formerly counted of little or no value, 5c. per gal. being a good price. No mention is made of it in the 1890 Census report on the Mineral Industries of the United States, all the distillations from petroleum being classed together as naphtha. Its rise in commercial importance may be referred almost wholly to the development of the gasoline engine.

It is a colorless liquid of highly characteristic odor, the latter quality serving for a highly fortunate warning as to its presence in case of a leak. Its specific gravity varies and it is considerably lighter than water, as it will float on its surface without mixing.

219. **Grade.**—All gasoline used for engine purposes had formerly to pass the Baumé test around 70° to 74°, 76° being the highest grade. Owing to the increased demand and scarcity, it has been recently announced that nothing better than 64° gasoline will be supplied through the general market. This is only two degrees above the limit below which the product is no longer called gasoline, but carburetor construction has advanced so much in recent years that this lower standard will probably give no serious trouble; in fact, not only kerosene but the distillates are coming into quite general engine use. Some of these low grade products stand higher in thermal value than gasoline,

but they are more difficult to vaporize and contain more solid matter like carbon.

220. **Tests.**—Quality tests are less important now than when the best of carburetors could only vaporize the best of gasoline; still, there are times when a few simple tests are convenient.

The volatile qualities may be determined by pouring a few drops into the hand and noting how quickly the liquid disappears. With 74° gasoline the hand should be dry in from seven to ten seconds. Sixty-two degrees gasoline should require from a quarter to a half minute; the lower grade products even longer time. Any unevaporated residue remaining in the hand means some non-volatile substance, and trouble for the engine. If the residue is sticky, the gasoline is of a grade unsuitable for engine use, or else it has been adulterated.

Water can readily be discovered by pouring the liquid into glass. The water will sink to the bottom and a sharp line of division will be seen.

221. **A Good Storage System.**—A good storage system without leaks is the best insurance policy in the handling of gasoline. Without this, no other sort of insurance will avail. Barrels and tanks stored carelessly in barns for even a day are not to be tolerated. Gasoline is far more difficult than water to confine and, aside from the danger, a very small leak may permit the escape of as much gasoline as an engine would use. An underground tank is best, where the temperature is cool and unvarying. Three pipes should connect with the surface; the one terminating in a gasoline pump; a second ending in a plate and plug through which the tank can be refilled, and the third, a smaller pipe, for ventilating purposes, should be discharged in the air several feet above the ground, where the

gasoline vapors will be diluted before reaching the ground, where there might be danger of ignition. Fresh air will enter the tank through this pipe to replace any gasoline drawn out but the heavier gaso-

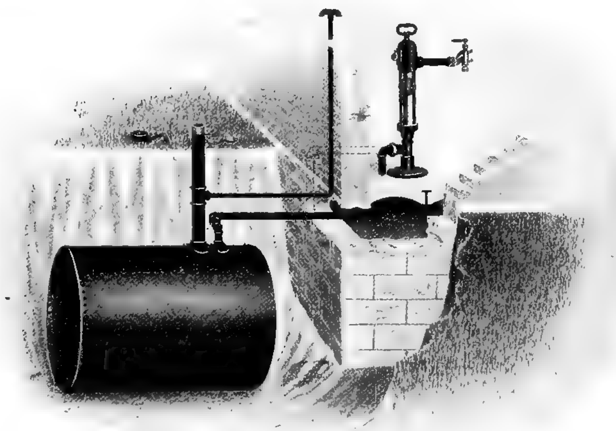


FIG. 66.—A Bowser Gasoline Storage System.

line vapors will not rise up and escape from it unless driven out by internal pressure. While the tank is being refilled these vapors, mixed with air, are forced out and form almost an ideal source for an explosion. ONE OF THE GREATEST GASOLINE DANGERS IS FROM THE VAPORS DRIVEN OUT OF THE VENT PIPE AND CONTAINED IN THE PIPE WHILE THE TANK IS BEING REFILLED. Fire and lights of all kinds must ALWAYS be kept at a distance while filling a tank.

222. A Good Tank.—The tank should be cylindrical. Copper is best for the smaller sizes, but for

a large tank steel does very well. Galvanized iron is often used, but zinc coatings are sensitive to the sulphuric and other acids used in breaking up the petroleum to increase the yield of gasoline. This causes a sediment that may at any time close up a feed pipe, and the metal itself is sooner or later perforated by that most dangerous of "pin-hole" leaks. These

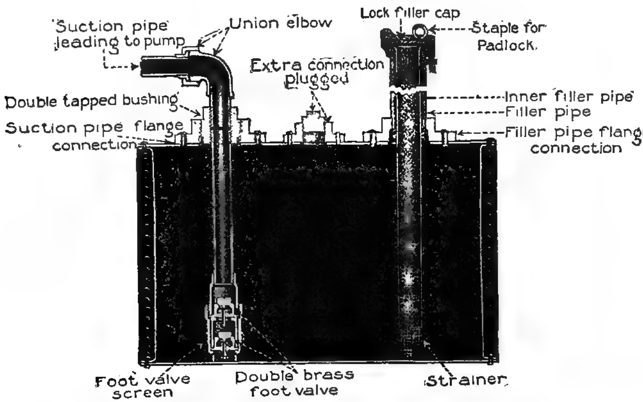


FIG. 67.—Bowser Gasoline Storage Tank With Convenient Fittings.

acids do not attack tin, and a heavily tinned tank, as nearly seamless as possible, makes a first class receptacle.

223. The Foundation.—Tanks should be solidly placed on broad bearings and rigid foundations. A hundred-gallon tank when full weighs something like 800 pounds, and the foundations should be planned not only to support this weight, but to so distribute it that not all the strain will come upon one portion of the tank.

224. The Connections.—Flexible copper tubing of not less than ¼-inch inside diameter is the best con-

nector with the carburetor, as it resists vibrations of the engine better than soldered joints. Brass pipe with threaded fittings well shellacked are satisfactory, while flared tube unions make excellent joints. Heavy lead pipe at least 3/8 inch is easily worked, and will give good service if not exposed to blows and bruises.

225. **The Joints.**—Joint leaks are specially hard to locate and produce leakage of gasoline. Several firms make a specialty of gasoline fittings, and the standard ground union made by one of these is excellent; also one with two flat surfaces to be drawn together, with a paper gasket set in shellac. A well made globe valve or a ground pet cock answers the purpose nicely, and has the advantage of having no gland with packing. Some such closing device should always be placed between the supply tank and the carburetor to shut off the gasoline when the engine is not running. To depend upon the carburetor alone is very unsafe.

226. **Guarding the Feed Pipe.**—The bottom of the filling pipe should be provided with a good screen strainer, and another should guard the mouth of the small feed pipe leading to the carburetor. This is small in diameter, and a very small scale or grain of dirt in this may be enough to put the engine out of business and provide plenty of business for the operator.

227. **Gasoline Dangers.**—Nearly all gasoline dangers consist of either leaks or carelessness. With a good storage system properly installed, the careful engine owner need have no fear. No gasoline engine ever exploded, and never did a steam engine. Gasoline tanks and steam boilers sometimes "burst" when outside heat raises the internal pressure beyond safety limits; but gasoline itself is quite as non-explosive

in the true sense as is steam. The terms explosion stroke, explosion chamber, etc., are all misnomers which are justified only by popular use. Gasoline vapors, mixed with the proper amount of air, will ignite and burn with almost violent eagerness. A dry pine stick will burn more rapidly than green basswood; neither the pine nor the gasoline becomes a true explosive because the combustion is more rapid than that of something else with which we see fit to compare it. There is a vast chemical difference between even the most rapid combustion and explosion; hence gasoline should never be classed with nitro-glycerine, dynamite, gun cotton, nitrogen chloride, or any of the true explosives.

228. Gasoline Not Inflammable.—Neither is gasoline inflammable in its pure state. A bucketful of gasoline dashed on a fire might extinguish it as quickly as a pail of water would; still gasoline is not intended for a fire extinguisher, and this property is here referred to in order to emphasize the foolishness of applying it to all things that it **might** be used for, but for which it was never intended. In order to quench a fire the liquid must be present in such excessive quantity that its own temperature remains low until the fire is out; otherwise the heat would vaporize it and convert it into a gas which, mixed with air, might become inflammable before the liquid had time to quench the flame. This same thing may happen in extinguishing fire with water, the water being decomposed, in the presence of carbon (charcoal and burned wood), to carbon monoxide or water gas. This actually happened at the great Chicago fire; but the temperature at which water is thus acted upon is so high that the fire which reaches that temperature is very exceptional.

229. **The Exact Danger Point in Gasoline.**—Let us imagine gasoline and its vapors composed of several distinct layers or zones piled one upon another. The bottom layer is the liquid itself; that will not ignite. Directly above it is a layer of pure gasoline vapor which contains no oxygen, and cannot take fire. In the zone next higher a small proportion of air is mixed, though not nearly enough to support combustion. Let us now begin at the other side of our pile. Somewhere above this gasoline we know there must be a place which the vapors have not reached. Here we have pure air. Just below is a belt where there is a mere trace of gasoline; not enough to burn; but the next zone below is a little stronger. Now if the top of our pile consists of pure air and the bottom of pure gasoline, it is evident that at some place between these two belts is a spot where the mixture is exactly right to support the most complete combustion of which the air and gas are capable. It is also certain that a lighted match dropped downward from above must reach this inflammable zone before it comes to one so dense in gasoline vapor as to extinguish it. It ignites that zone and the disturbance so far mixes all those nearer to it that almost the entire vapor pile becomes in an instant a mass of burning gas, the heat and current from which almost as quickly convert the liquid itself into seething flame.

230. **Small Danger in Tank from Natural Causes.**—Unless the gasoline is being subjected to more than normal heat or the air and vapors above it are agitated and mixed by some mechanical means, the proportion of inflammable mixture existing at one time in a closed tank is very small. The greatest danger consists of its ready ability to mix up an inflammable proportion out of the surrounding material.

The air enclosed in a tank soon becomes saturated, and not inflammable; hence there is practically no danger of a flame from the engine following the tube

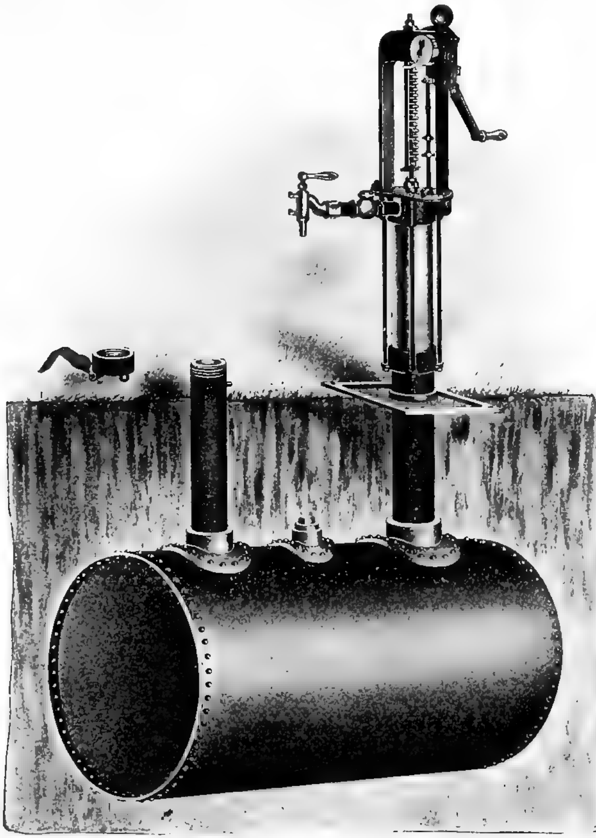


FIG. 68.—Bowser Underground Tank With Measuring Pump Attached.

back to the tank. The liquid gasoline in it would prevent, or, if it did not, there would be nothing inflammable in the tank.

231. Rules for Safety.—Gasoline can, however, be easily made dangerous; and a great many people are getting hurt through ignorance or carelessness in its management. It is always the free gasoline outside the tank that causes trouble; that which has leaked out or been purposely drawn and exposed to the air. Leaks should constantly be watched for. When found they should be remedied at once.

No poorly ventilated room through which gasoline pipes pass should ever be entered with an open light until the air is tested for gasoline vapor. For most people, the nose is a partial test and one which should not be disregarded. Never bring a light into a room where there is a noticeable smell of gasoline.

Gasoline vapors are much heavier than air, and will be strongest usually near the floor; hence the room should be ventilated from below.

The leak that is searched for with a lighted match will surely be found, but the searcher may not be.

Gasoline may be evaporated in an open dish by boiling without ignition, but as soon as the heavy vapors settle down to the flame, the room will make a first class combustion chamber for one power impulse only.

One of the commonest dangers in the handling of gasoline is its use in small quantities for cleaning purposes, after which it is discarded into the sink or slop bucket, where it will surely come to the surface and vaporize. In time, enough of the heavy vapor is likely to accumulate in the lower part of the room to spell disaster.

Gasoline should never be drawn from a common spigot or poured from one vessel in the presence of flame, as the process exposes a large surface to vaporization and the fumes come off rapidly. For this rea-

son gasoline should never be drawn in the presence of another person, who is liable at any instant to carelessly light a cigar.

Gasoline, in fact, should not be poured at all; it is too wasteful. If drawn from a barrel, lower a length of rubber hose into the barrel, then pinch the end tightly between the fingers and draw out until the outer end of the hose reaches below the level of gasoline; then release the end and siphon out the desired quantity.

232. **Two Fundamental Rules.**—1st. Avoid evaporation as much as possible by keeping the gasoline in a cool place and away from any but saturated air.

2nd. See that all vapor or air space in the storage system is kept constantly at the saturation stage. This can always be assured by keeping all tanks, pipes and joints constantly tight and a supply of liquid gasoline within them.

233. **Common Risks and Errors.**—Do not expect to locate a small leak by dripping liquid, or even by moisture around it. In such quantities it is the nature of gasoline to vaporize and become invisible the moment the air is reached.

Do not use a dirty stick to measure the depth of the gasoline in the tank. It may result in a clogged pipe. Keep a clean rod in a clean place for that purpose, and have the scale in inches and fractions marked at its lower end. Some lower a glass tube, open at both ends, then close the upper end with the finger and draw out and note the height of gasoline in the tube.

Do not use the same funnel for gasoline, lubricating oil, and kerosene. These are sometimes fed to the engine in mixture, but each funnel develops dirt enough of its own.

Rubber tubing is not suitable for piping gasoline, kerosene or lubricating oil. The first dissolves it readily, while oil and the fatty remnants of oil left behind when kerosene evaporates soon rot the life out of rubber. Specially treated hose is furnished for such purposes.

All gasoline joints should be unfailingly made up in shellac. A single joint that is merely "good enough to answer" may defeat all the other precautions and render them care and money thrown away.

Unfiltered gasoline is very likely to cause a troublesome interview with the intake pipe or carburetor sooner or later.

Never forget that the greatest danger about a gasoline tank is the process of filling it; while the saturated air is being displaced by the inrushing liquid and forced into the open air to be diluted to the most combustible point. Then the cigar-lighter gets in his deadliest work.

Wire screen strainers alone are not enough protection from dirt. The needle valve is small and easily clogged. A chamois skin at some convenient part of the system not too remote from the carburetor is a great trouble saver.

Do not attempt to solder a spot in a galvanized tank that has rusted through. Occasionally it pays, but it is usually a waste of time.

The gasoline that has stood for some time in the carburetor of an idle engine may lose its more volatile elements and become useless as an engine starter. Better drain the carburetor and renew the supply.

Make it a rule never to draw gasoline at night under conditions where a light from a naked flame is necessary. The occasional exception may not prove dis-

astrous, but it will soon become the rule and serious consequences are sure to follow—some time.

A bottle of mushy yellow shellac and a few strips of cloth should be in every gasoline engine repair chest. This will repair a leaky union temporarily without shutting down the engine until the run is

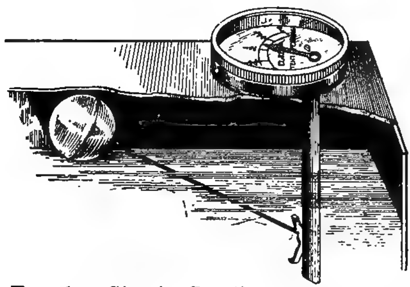


FIG. 69.—Simple Gasoline Tank Gauge.

finished. Sometimes, when this fails, relief may be obtained by shutting off the gasoline, unscrewing the union, and making up the joint in soap or graphite.

Remember always that, aside from the danger, even a small leak may consume gasoline faster than the engine does.

234. **Gasoline Fires; How to Handle Them.**—The most important thing to do with a gasoline fire is to prevent it, and the next thing is to smother it out by cutting off the air supply, or the gasoline. Fighting with water is time worse than wasted; it spreads the gasoline over a larger surface and increases the area of evaporation. Sand and sawdust are two of the very best extinguishers, though sand should not be used too near the engine, as grains of it in the cylinder may cut and ruin it. A few buckets of sawdust near a gasoline engine or storage system should

be as much a part of the equipment as buckets of water are around the furnace of steam boilers. It not only smothers but absorbs the liquid and prevents its spreading, while a few grains drawn into the engine will not do such serious damage.

If sawdust is not available, old carpets, blankets, binder canvas, stack covers, anything to shut out the air, should be resorted to. Out of doors, a few shovelsful of dirt may be sufficient and most readily obtainable. This has the same objection around the engine that sand has.

Chemical fire extinguishers are many of them all right. One of the very best may be made by mixing common salt and sal-ammoniac in equal parts; then add to the mixture two-thirds of its bulk of bicarbonate of soda. Mix and screen thoroughly; then bottle for use, and keep in stock for an emergency. A little of this scattered over a gasoline fire will conquer it quickly.

235. **Kerosene: Its Advantages and Drawbacks.**— In thermal heat value kerosene stands higher than gasoline in the proportion of about 22 to 18.

Nearly every one is familiar with kerosene and its treatment, while gasoline is with many people a series of experiments.

In some parts of the country gasoline is only obtainable at certain stations, while kerosene can be obtained at any corner grocery. If the fuel supply runs out before a certain job is done, a few gallons of kerosene can be brought in the farm buggy, enough to finish the work without having to shut down.

If a few gallons happen to remain over at the end of the season the housewife can burn it in her lamps. It does not have to be carried over till another year. This argument is hardly valid, however, in the case of

small engines, as they are likely to be in daily use the year around.

Insurance companies are more generally educated up to the point of tolerance in the use of kerosene, and are not so strict in their ruling as they are with gasoline. Perhaps they realize that people know better how to handle it.

Various experiments have proven that the same amount of work can be done cheaper with kerosene than with gasoline, the difference being due both to the lower price for kerosene and its superior thermal efficiency.

Kerosene is somewhat safer to handle, both because it is less volatile and because it is more generally understood. Under ordinary conditions if it happens to escape from the tubes within which it is supposed to be confined in the form of a liquid it remains a liquid. This superior stability, however, is also one of its chief drawbacks.

236. **Objections to Kerosene.**—It is much more difficult to vaporize in the engine than gasoline; in fact, artificial heat has often to be applied to it at the beginning of a run in order to start at all. When once started the engine itself supplies the heat.

Kerosene is not so fully consumed in the process of combustion as gasoline, and there is a much heavier deposit of carbon on the valves and in the cylinder. The piston rings must be cleaned oftener, and there is greater trouble with pre-ignition and leaky valves.

Kerosene engines are apt to be offensive to the sense of smell. Not only that, when used in the stable or dairy, the milk has to be much more closely guarded or its products are likely to taint.

Kerosene engines are more liable to smoke than

gasoline, and are less available for interior work, especially in laundries, kitchens, milk-houses, etc.

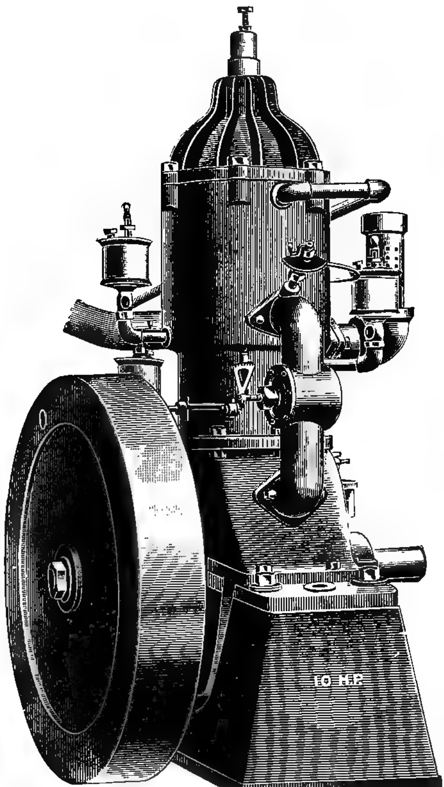


FIG. 70.—Typical 10 H. P. Kerosene Engine.

237. **Which Is Best.**—For tractors and out-of-door engines kerosene and the distillates are specially available on account of their cheapness and superior power, but for small units and for in-door work the gasoline engine is probably enough better to pay the difference

in the cost of fuel. Gasoline, too, is best for high speed engines, as kerosene is much slower burning.

238. **Changing for Kerosene from Gasoline.**—Almost any good gasoline engine can be used for kerosene by a few minor changes. Two supply tanks are needed, a large one for the kerosene and a small one for gasoline. In starting the engine the gasoline should be turned on first until the iron is well warmed up; then the gasoline can be switched off and kerosene turned on. A few minutes before closing down at night it is well to change back to gasoline; then the carburetor will be charged with gasoline in the morning for starting. Short shut-downs in the course of a run do not usually require this change, as the engine, once hot, remains hot enough for a reasonable time to vaporize the kerosene. If at any time it will not start, the carburetor should be drained and then primed with gasoline.

A good spark and good compression are essential for the use of kerosene. Without these it is generally a waste of time to attempt the change. Kerosene is more suitable for constant than for variable loads. Valves and connections must be kept tight, and rings and sparker clean. Sometimes it is necessary to pipe hot air from some part of the engine across the carburetor, or a hot water jacket can be used. The spark must not be advanced too much or pre-ignition troubles are likely to come up. Some engine operators favor mixing a quart of gasoline with each five gallons of kerosene, while others operate successfully on kerosene alone. Under favorable conditions a saving of as much as forty per cent. has been reported by changing from gasoline to kerosene, and with an increase of power.

239. **Distillate.**—Distillate, which is really a low

grade of kerosene in which more traces of the heavier oils remain, can be used in most gasoline engines in the same way kerosene can, and, like the latter, it is more desirable for tractors and heavy engines of low speed than for the more speedy affairs for indoor work. Some of the advantages which kerosene presents are not so marked, while others are more so. Also, the main objections to kerosene appear in distillates in an aggravated form; still they are valuable in their place, when properly arranged for, and are among the very cheapest engine fuels.

240. **Alcohol.**—This is the great unfulfilled promise, to the industrial world, of the internal combustion engine; indeed, it was regarded as so important that a few years ago special revenue laws were enacted in its favor, and it was confidently expected that denatured alcohol would revolutionize the small power industries.

241. **Its Advantages.**—In many respects alcohol is specially fitted for this work. It is far cleaner and less odorous than gasoline, and greater power is obtained from it for a given weight of engine. A gasoline engine operating under ordinary compression of about 70 pounds will increase in power about 10 per cent. when run on alcohol; then by increasing the compression to 180 or 190 pounds, which could not be done with gasoline, the power will be nearly 30 per cent. greater. It will thus be seen that in order to run on alcohol economically a much higher compression pressure should be provided for than either kerosene or gasoline would permit.

242. **Some Peculiarities of Alcohol.**—Alcohol combustion is slower than gasoline, and less noisy. The heat from the flame goes up instead of spreading out, and a fire caused by it spreads less rapidly and is

readily extinguished by water, with which it mixes greedily. All alcohol contains some water; and its presence in the engine in the form of steam sometimes has to be considered. It has also a troublesome habit of corroding metals and of changing lubricating oils to gummy substances. It is more constant in its composition than gasoline in its action and will stand overloading better. It will operate the engine, too, when diluted with water as much as 50 per cent.

243. **Its Fatal Weakness.**—So far its fatal weakness has been the prohibitive price and its low thermal value. In heat units it is much lower than gasoline, the relation standing about in the proportion of 2 to 3, while the proportional price is more than reversed.

244. **The Engine User's Dream.**—It has been an unrealized dream of power users that alcohol will some time be produced on the farm or in each farming community from farm refuse, like small potatoes, etc., at a low cost. It would then be almost an ideal and inexpensive source of power, of local production and not subject to excessive tax of transportation. The power, too, that could utilize the present waste of the farm and be independent for its source from any other industry must of itself, if ever realized, be of inestimable advantage. Thus far, however, there has been little progress made in a realization of this dream, and at its present prices alcohol as an engine fuel can only be regarded as a promising possibility of the future.

245. **Notes on Fuels.**—In spite of the fact that gasoline is much more costly now than it was a few years ago its use as an engine fuel is less so because of greater carburetor and general engine efficiency.

American oils furnish on an average about 54 per cent. of kerosene and only 6 to 8 per cent. of gasoline.

Gasoline cannot be ignited by overheating a tank, but it can be made to vaporize until the internal pressure may burst the tank.

The only dangerous gasoline is free gasoline, and the entire danger from operating the gasoline engine may be said to consist of failure to confine the fuel. The difference in the cost of a good and a poor job in the installation of the storage system should not be considered.

It is the weak point of the storage system that the gasoline finds. Those parts that are strong enough are never in evidence.

Any float-controlled valve may become clogged with dirt and fail to seat properly. This means a leak as surely as a rusted pipe.

White or red lead is not suitable for making up a gasoline joint. The gasoline attacks and cuts them out. Litharge and glycerine mixed to a thick paste are excellent—as good as shellac.

Alcohol dissolves shellac and soon attacks the usual float found in the ordinary carburetor, permitting it to become fuel-soaked and unreliable.

One pint of gasoline or 1.1 pints of kerosene or 1.4 pints of alcohol should produce on an average one horse power per hour. At that rate, with gasoline at 14 cents per gallon, alcohol should cost 10 cents, and kerosene 13 cents; or, with alcohol at 30 cents, gasoline at 40 cents would still be as cheap.

Many accidents arise from the storage of gasoline and kerosene in small quantities in similar cans. To prevent this paint all gasoline receptacles on the outside a bright red. In some states this precaution is required by law, as it should be in all by common sense.

CHAPTER XII.

LUBRICATION.

246. Importance.—If intelligent lubrication could become the gasoline engine owner's politics it would be well for him to be in the throes of a great national campaign continuously. More machinery is sacrificed each year to the god of friction than to all other legitimate causes; and the shame of it is that much of this is easily prevented.

Not only does carelessness in lubrication destroy machinery, it seriously diminishes the amount of energy available in useful work by introducing a great amount of needless and unproductive work. The efficiency of any power may be reduced as much as 50 per cent. through lack of proper attention at the bearings. The fire risk is also greatly increased by it. Destructive fires are so often started by hot boxes that the rate of insurance upon any building containing machinery is considerably higher than normal.

247. Purpose.—An ordinary cast iron cylinder shows to the naked eye a rough surface covered with sand-holes and foundry defects. It is easy to see that such a bearing would not be permissible in even the slowest of moving machinery. Steel and some other metals may present a smoother surface, but we would not think of using any of these in journal boxings until the surface was worked to a true circle and then polished until all of these defects which we readily see have been removed.

The most highly polished metal surface known to mechanics will, under a powerful microscope, present an appearance not unlike that which the unfinished iron gave to the naked eye (Fig. 71), and friction

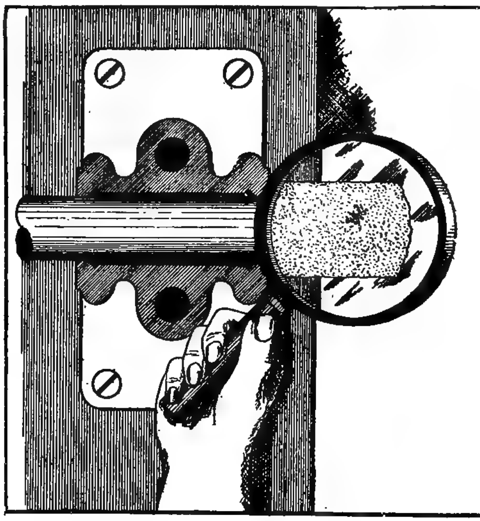


FIG. 71.—Polished Steel Rod Looks Rough If Magnified Greatly.

works with microscopic exactness. The hardest steel is not incompressible either; and, unless we are willing to furnish the extra power energy to tear these multitudinous inequalities of surface apart and grind them down by main force, we must render the shaft more smooth.

248. How Lubricants Work.—Some lubricants accomplish their mission almost wholly by filling up these minute holes and inequalities, and then, under the pressure, forming a new surface of their own composed of the little globules of oil pressed and ground into each other until they form a smooth, hard glaze.

Others do their work more by dividing into little elastic balls which cover the bearing surface constantly with self-adjusting ball-bearings, interspersed with cushions of imprisoned air. Either of these effects prevents the two metal surfaces from ever coming together and, under perfect lubrication, nearly all of the wear is on the lubricating surface itself. Of course, in practice, lubrication is never continuously complete; and, even if it were, some friction would result between the metal and the oil; but the latter, being the more yielding, would bear the brunt of the wear.

249. **What a Lubricant Is.**—Practically any liquid is a lubricant, since all liquids are composed of easily moving molecules or globules which readily adjust themselves to any surface. Not all liquids can be made to stay in place, nor have all of them strength or body enough to hold a heavy shaft clear of its bearings. In order to resist the tendency of the scraping metal to tear the lubricating film apart and let the metals come together, the liquid globules must have a strong inclination to stick together; that is, the liquid must have good cohesive properties. It must also adhere well to the metal surface it is applied to, or the moving shaft will shove it aside; in other words, it must have good adhesive powers.

250. **Viscosity.**—These two properties determine the viscosity or body of a lubricating agent, and in a great measure fix its lubricating value. Many liquids possess one of these qualities without the other. Water adheres well to the metal but does not stick together with enough persistence to prevent the metal surfaces from shoving it aside. Mercury is exceptionally cohesive but has not sufficient adhesion to hold it to its work against the other metals. Neither

of these two fluids will do as a lubricant because neither of them is truly viscous.

251. **Fluidity.**—Fluidity is just the opposite of viscosity. There is a certain amount of friction between all moving things which are in contact, not excepting the separate particles in the oil itself; and this internal friction or tendency to cling together is greater in the kinds of liquids which are less fluid. This stationary tendency in an oil increases its resistance to all motion, including that of the shaft, and after the point is reached where the oil has sufficient body to sustain the required load, any addition to the resistance is only adding to the friction between the oil and shaft without serving any useful purpose.

252. **The Flash Point.**—In gasoline engine lubrication the flash point and fire test of the oil are of very great importance. The first refers to the lowest degree of temperature at which the vapors from the oil will flash into momentary flame and then die out; the second to that point at which the vapor will continue to form and burn constantly. As the temperature in the engine cylinder is so high, it is necessary that a good cylinder oil have a very high test in both of these, else it would be ignited and consumed before having a chance to do its work. A fire test of 400° F., or more than the working temperature of the cylinder, is necessary, and some gas engine men insist on as high as 500° or even 600°.

253. **The Cold Test.**—The cold test is of less importance; still it should be considered where machinery is to be run at a low temperature, as oil which is so nearly congealed that it will not follow in its proper channels is of no use as a lubricant. The usually accepted cold test for gasoline engine oils is around 20° Fahr.

254. **Carbon.**—In the cylinder oil the per cent. of carbon is of very great importance, since each impulse of the engine consumes all the inflammable parts of the oil in the cylinder and leaves the free carbon and other unconsumed ingredients behind to gum the piston and rings with their troublesome deposits.

255. **Gums and Acids.**—Gums and acids, though present in most oils, are a detriment for obvious reasons, and an oil should be selected which is as free from them as possible. Acids, of course, attack the surface of the metal the oil is intended to protect and lubricate, while gum in cylinder oil is not to be tolerated, as it is constantly depositing a few more engine troubles in the cylinder.

256. **Variety in Lubricants Needed.**—No one kind of oil is best for all machines or all parts of the same machine. A thick lubricating film of good resisting body is needed under the heavily loaded shaft, and for such heavy machinery its greater internal friction is of no importance, the weight and momentum of the machine being enough to overcome the extra resistance without being retarded. For the light spindle of high speed such heavy oil would be unnecessary, and its retarding tendency would be serious. A drop of thick cylinder oil would put a watch out of commission, while a gallon of typewriter oil would be worth about as much as the same quantity of water to lubricate the line-shaft of an ocean steamer or the drive wheels of a locomotive. Friction between certain kinds of metal, too, it has been proven, is best reduced by certain oils, while the temperature at which the machinery works is an important matter. In comparison tests of good oils of seemingly similar nature it has sometimes been found that three-fourths of the oil required of one brand will accomplish more

work with the same machine and load than some other brand would require, and that there would be a material saving in power and repair bills at the same time.

257. **Gasoline Engine Cylinder Oil.**—This is perhaps the severest known test ever placed upon a lubricant of any kind. Ordinary cylinder oil which is satisfactory in the moist air of the steam engine cylinder, where the temperature rarely gets above 400°, will not answer at all in the presence of this dry heat of 1,500° or more at the moment of firing, and a continuous wall temperature of 350° or more. The oil would be burned up at once and the released carbon, uniting in the presence of the heat with the oxygen in the cylinder, not only chokes the engine up with dirt but, by removing some of the oxygen, interferes seriously with the firing of the charge.

Gasoline engine cylinder oil must have enough viscosity or adhesive stickiness to carry its load well at these high temperatures and still be free from gum. It must have an exceptionally high fire test in order to resist consumption until after its work is done; then it must suffer as near complete consumption as may be, in order that but little deposit from it remains to trouble the cylinder. It should have a good cold test also, and it must be free from the various adulterants which are sometimes used to make cheap oil resemble high grade cylinder oil in its "handling" qualities.

Cheap cylinder oil should be avoided, because a good oil cannot be made cheaply. It requires many filterings until practically all of the impurities are taken out of it. It is then nearly colorless, like glycerine, instead of the dark green or amber frequently seen on the market; but color alone does not

prove the quality. Oil can be bleached by certain acids until it resembles the highly filtered oils; then it contains, in addition to the objectionable carbon, a certain amount of free acid to attack and roughen the cylinder walls. Soap, alumina, soda, lime, etc., are often present in cheap oils. Their uses are many to the oil vendor. For the engine owner they accomplish one result only—trouble.

258. **Bearings and Their Requirements.**—The weight and strain upon a bearing and the speed at which the shaft is run in the main determine the nature of the best lubricant for most parts of ordinary machinery, including the gasoline engine, though the method used in its application may have much to do with it. The viscosity should be sufficient to carry the load and not much more. The oil should be fluid enough to freely enter the most difficult parts of the boxing channels, and the flow should be ready enough to insure a constant supply. The fluidity of the oil is specially important when some parts of the bearings are difficult of access or when the splash system of oiling is made use of. On the other hand, there are places where a thicker oil, even grease, is better for ordinary journals; for instance, near an emery wheel, where bits of metal or grit are likely to abound. Its thicker body tends to protect the revolving surface from abrasure and to work the foreign particles outside the journals. Where drip from the ends of the axles is specially objectionable, too, the heavier oils and greases are more appropriate.

259. **The Specific Purpose.**—About the only way for the machine man to really know what oil is best for any specific purpose is for him to understand the nature of the different oils and then study the requirements of his machine, and select that oil best adapted

to supplying them. To know the machine alone is not enough. There are some oils that might be specially valuable under certain conditions, which possess some peculiarity that under other conditions would render them valueless in the same machine. Tallow and lard oil, for instance, so largely used on farm machinery, have practically no lubricating value where there is much load if the temperature gets above 100°, because their viscosity is then destroyed, and they have not sufficient body to hold the two metals apart. Beef suet, a favorite with some, will not begin to feed down until the boxes have become hot enough to be injured. This is almost a fatal weakness in its lubricating properties, it being the purpose of every good machinist to prevent hot boxes rather than to provide them for the purpose of melting his grease. It is always well when selecting oil to consider the temperature of the place, and to remember that high temperatures readily decompose the animal oils and render them rancid.

260. Animal and Vegetable Oils.—Formerly the only oils in common use as lubricants were of animal or vegetable origin. This was largely due to their cheapness and greater supply. Animal oils are more oily, however, than mineral, and they mix better with moisture. For the latter reason they are more desirable around steam than gasoline engines, though even for steam they are not ideal. As a class they are more oily than the hydrocarbons or mineral oils, and some of them are said to hold their viscosity better. They all contain oxygen, however, and so are subject to atmospheric changes, and form fatty acids which attack the metal. They are also liable to develop internal heat, and become a serious fire menace through spontaneous combustion, a property that the mineral

oils do not possess. The chief animal oils are sperm, lard, neat's-foot, tallow, and whale oil; the best known vegetable oils include olive, rape, castor, palm and cotton-seed. Of these sperm oil is specially good, but

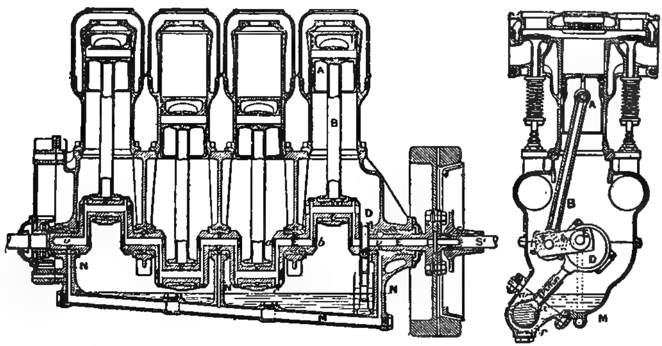


FIG. 72.—Section Through Four Cylinder Motor, Showing Lubricating System.

not for heavy loads at high temperatures. The vegetable oils as a class are particularly volatile.

261. Mineral or Hydrocarbon Oils.—The mineral or hydrocarbon oils are obtained from crude petroleum by driving off the more volatile elements and then refining by acids and filtering what remains. This is technically known as the cylinder stocks. The paraffin distillates, which are somewhat lighter, are separately refined and the oil pressed from the flake paraffin, which is then purified. From this oil come the heavy engine oils, of high velocity. Out of the general classification comes a variety of brands, many of them arising from a difference in the characteristics of the crude oil taken from different fields. The Ohio oils, for instance, contain more or less sulphur and asphaltum, while Texas oils, though free from sulphur,

have fully as much asphaltum. The Texas oils have a purple bloom and are specially desirable, because of their fine cold test, in refrigerating works. Pennsylvania oil has a distinctly greenish bloom and is much used in the cylinder oils of commerce.

262. **Testing Oil for Acids.**—Mix a little oil with alcohol which has previously been heated to about 120°. After several minutes dip a slip of litmus paper (obtainable at any drug store for a few cents) into the mixture. If the paper remains blue there is no acid; if it turns red, acid is present. Or saturate a bit of waste or cotton with the oil and leave for eight or ten hours in the sunlight on a highly polished metal surface. Even a slight corrosion denotes free acid. A third test, rub some of the oil over a bit of polished brass and leave for twenty-four hours. If acid is present the metal will turn green. It is needless to add that oil which contains free acid will injure metal surfaces and is objectionable, as it soon roughens the bearings.

263. **Testing for Viscosity.**—The relative viscosity or body of two different oils may be determined by placing a drop of each side by side upon an inclined pane of glass. The thinner oil will of course run the farthest in a given time. By keeping a systematic record of all the different oils used and tested, one may soon have a very good knowledge of the comparative body in the different oils he has used, and so determine the one that suits his purpose best; providing, always, this test is always made at the same temperature and with the glass always equally inclined. Another relative test is by counting the drops that fall from a small orifice, the two oils under the same temperature and pressure.

In testing viscosity it should be remembered that

the practical man is interested in the body which the oil shows at about the temperature which will be maintained while in use, rather than in its behavior in the oil barrel.

Often the viscosity can be determined after a little experience by pinching or handling the oil between the thumb and finger. This test the adulterer has interfered with by introducing resinous or gummy matter in the oil to give it body. In order to determine this a quantity of the oil may be weighed and then ignited in a crucible until the carbon is burned out. If more than a tenth of the original weight is left in the ash residue the oil has been thickened with some adulterant.

264. **Testing for Adulterants.**—Adulterants may frequently be discovered by mixing a quantity of the oil with one-tenth its bulk of caustic soda dissolved in 95 per cent. alcohol. Fatty adulterants become gelatinous or solid when cold.

265. **Testing for Gum.**—Going back to our first viscosity test, we may leave the oil on the inclined glass for an hour and then attempt to wipe it off. If it comes off clean it is free from gum; if a sticky streak remains the oil should be rejected. Another test: spread a thin layer of oil over a glass pane and expose to sunlight but protect from dust. A gummy oil soon becomes sticky or tough. A still more definite test: barely cover the bottom of a shallow dish with oil and heat to about 250° F., then cool slowly. When cold there should be no gummy residue.

266. **The Flash Test.**—As the gasoline engine cylinder oil is used in the presence of excessive heat it is highly important that both the flash and fire test should be exceptionally high, though of course not nearly so high as the excessive heat to which it is for

a moment exposed at the instant the charge is fired. About the only satisfactory test of this requires a special thermometer whereon the reading goes much higher than the ordinary temperature thermometer; not less than 400° Fahr. Place a small metal or thin porcelain dish filled with oil in a larger vessel which has been filled with sand, sinking the fire well into the sand; then apply heat until the oil begins to vaporize. The sand bath is for the purpose of heating all sides of the dish evenly instead of all at one point of contact. Hold a lighted match above the dish in the midst of the rising gases until there is a flash or ignition; then note the reading of the thermometer. This is the flash point; that is, the lowest temperature at which the oil vapors take fire and then go out.

267. **The Fire Test.**—The fire test is the same as the flash test, but is carried a little farther, as the firing point is the lowest temperature at which the vapors not only ignite but continue to burn. This should be from 60° to 75° higher than the flash point.

268. **The Cold Test.**—There are some instances where the cold test of an oil is of considerable importance, specially where the engine is to be operated much in low temperatures. The congealing point of any oil is easily taken by actual experiment. It should always be remembered though that after an oil has shown anything like reasonable working qualities at low temperature the test should not be too rigid, since extra superiority here is apt to mean a sacrifice of the other extreme. After all, a good cold test is more nearly a matter of convenience, while a high fire test is a positive necessity.

269. **Carbon.**—The specific gravity of an oil is a pretty accurate guide to the carbon it contains, pro-

viding adulterants have not been added. As the heat in the cylinder is enough to burn and evaporate any oil more or less, and as this drives out the hydrogen, it follows that the oil richest in carbon will deposit the greatest load of dirt and trouble. All of these oils deposit some carbon when they burn. That oil which is of lightest weight and still possesses body enough to do its work is best, where specific gravity alone is taken as the test. By igniting a quantity of the oil in a small vessel and holding a bit of window glass over it for a stated length of time while it burns, the amount of carbon it deposits can be readily approximated.

270. **Oil Waste and Engine Waste.**—No thorough test of the lubricating system has been made that does not include the man behind the oil can. The oil that is squirted carelessly over the outside of the frame is of no value to the engine, though it serves an important mission in an accumulation of dirt. A gasoline engine, if it is to do good work, must be kept clean, but this cannot be done unless good oil is used and not unless it is used properly. Where lubricators are not used it sometimes requires considerable judgment to know just when to oil; when they are, one must know how to set them.

271. **Quantity of Oil.**—For the new engine the cup supplying the piston and cylinder should be set to supply about 25 drops per minute, until the walls have begun to acquire their glaze and the engine itself has become tuned up for smooth working; then the supply may be reduced. The exhaust is a good indicator if too much oil is being used, a heavy blue smoke being pretty conclusive evidence that there is. Too much oil is better than too little, but it is not very much better, for it soon loads the piston and rings down

with a sooty deposit and is very likely to short-circuit the firing plug.

The quantity of oil needed by the other bearings can best be told by careful attention, always remembering that some bearings tell the engineer when they are dry while others only tell their troubles to the engine. It's always best to keep on familiar terms with them.

272. **Lubricating Systems.**—While there are many lubricating devices and systems in common use, those described below will probably prove of greatest interest to the owner of a farm engine.

273. **The Gravity System.**—The gravity system, much in favor some years ago, depends for the flow

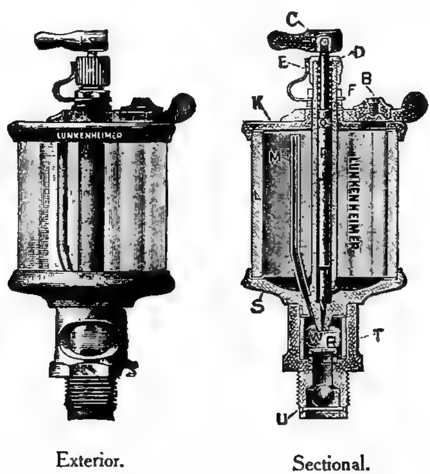


FIG. 73.—Exterior and Interior Views of Sight Feed Gravity Lubricator.

of the oil upon the elevated location of the cups through a small outlet pipe from which the flow can be regulated to very nearly a stated number of drops

per minute. While these are fairly accurate it does not require a very great obstruction to cut off the flow, as the pressure from the oil above in so small a channel is insignificant. This style, however, is in very common use, in part because of its simplicity.

274. **The Splash System.**—The splash system requires a tight oil case enclosing the crank shaft. Enough oil is placed in the bottom of the crank case that the ends of the connecting rods dip or splash into the liquid on their downward thrust, at every revolution, and so carry up enough oil to the working parts of the shaft and crank to supply them. Enough oil can be placed in the tank at once to last for some time, and all surplus oil carried up is caught. With some people there is more chance of forgetfulness with anything which is automatic for days and then has to be attended to than with something requiring constant attention; still the same argument might be used against the use of a tank to hold a supply of gasoline ahead. The splash system is very effective so long as a supply of oil is kept in the tank. Occasionally, as the oil becomes discolored through use, it should be drawn off and filtered or new oil introduced.

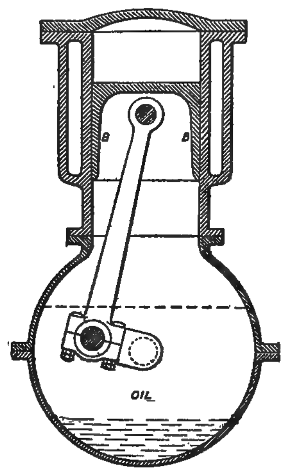


FIG. 74.—Explaining the Splash System of Lubrication.

275. **The Loose Ring System.**—This is very similar

to the splash system, a loose ring being allowed to swing upon the shaft and carry the oil up with it as it slowly revolves. It is hardly as effective as the splash method, however, and is less in use.

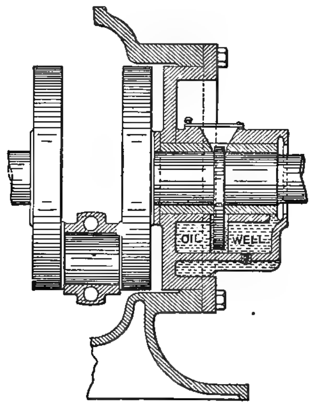


FIG. 75.—Loose Ring for Bearing Lubrication.

276. The Pressure System.—Sometimes the oil is held in a central tank or source of supply, into which pressure can be introduced. This forces it through connecting pipes with the various bearings and the pressure is maintained by connecting the tank with the exhaust or with an enclosed crank case.

277. The Positive or Force Feed.—A favorite method now because of its certain efficiency is the use of an oil pump which is geared to the engine and which forces a certain quantity of the oil through the various feed pipes attached to it with each stroke of the engine. This has several important advantages, and, with a supply of oil back of it, there is practically no danger of any bearing thus connected being overlooked. Of course, this system is not so simple as some of the others, and it is more costly to install.

278. Oiling Through the Carburetor.—While this method has hardly passed the experimental stage, enough success has been attained to render it worthy of notice; indeed, when the cylinder walls get hot and

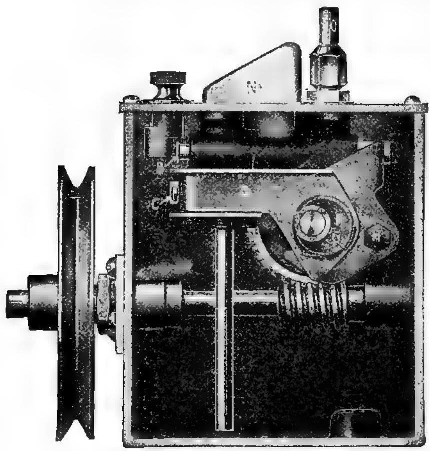


FIG. 76.—Mechanically Operated Plunger Oil Pump Insures Force Feed.

oil refuses to stay on them it is sometimes recommended to mix from a pint to a quart of the best heavy cylinder oil with each five gallons of gasoline and strain into gasoline supply tank. This divides the oil into fine globules which enter the engine cylinder readily through the carburetor along with the fuel vapor; still it retains enough viscosity to settle in a fine spray upon the walls and keep them lubricated, where other methods fail. When this method is used all other means of lubricating the cylinder and its immediate accessories may be dispensed with, though of course the bearings and parts contained in the crank case are not affected. These must be oiled through the cups, as usual. As the oil applied through the

gasoline is better distributed directly to the point where it is needed, less oil is required and less carbon, it is claimed, occurs in the cylinder.

279. **Filtering.**—Oil finally becomes unfit for use, not only through a mixture of dirt, dust and the metal particles which scale from the bearings, but through evaporation and actual chemical change. Still it may be used over again several times for the bearings if filtered, but even after filtering should not be used again in the cylinder. Ordinary wicking makes a good filtering material, though it may take filler out of oil or heavy compounding out of paraffin oil or that of high viscosity, and leave it without body. Oil may be filtered two or three times and used over. Even new oil should be filtered before using. This will remove much dirt and impurities that otherwise would be liable to make trouble in some pipe in the lubricating system.

280. **Other Lubricants.**—Perhaps this chapter would not be complete without a brief reference to a few supplemental lubricants so unlike oils in their nature that it hardly seemed best to refer to them under the same head.

281. **Graphite.**—This substance, which occurs in nature in both crystalline and amorphous form, when free from grit and impurities, is a true lubricant, and possesses for certain places several advantages over oil. It is not affected by heat or cold and is not acted upon by acids or alkalies. In its solid form, too, there are places where it will stand up under its work when resisting a pressure that would break liquid lubricants down. In some measure graphite is a supplement of oil in that it fills in and removes the inequalities in the surface to be lubricated, while the oil merely slides over them. Its glaze surface is probably more durable

and more the nature of metal itself in point of resistance against the breaking of the gloss than the best of oil ever becomes, and it has frequently happened that, applied alone or in combination with oil, it has succeeded in places where oil alone failed.

As graphite is so little affected by heat, it is specially useful in establishing a high glaze finish in the gasoline engine cylinder, where it may be introduced through the spark plug port with a teaspoon. If mixed with oil, use not over a teaspoonful to a quart of oil, and do not try to introduce it through the regular oil cup feed pipes. This is frequently done with entire success, but there is always risk of clogging.

By adding graphite to the cylinder lubricating system, faulty compression, when caused by any internal roughness, may be done away with. One engine user reports that after considerable trouble with his compression, by adding a teaspoonful of flake graphite each three hours during a twelve hour run the cylinder and rings of his engine acquired a mirror-like surface, and there was no trouble with his compression for three years.

In many power plants graphite is considered as much an essential as oil, especially where there are unusually heavy bearings with a low speed. Applied to valve stems in connection with valve oil, it is a complete success; also when made into a paste with oil and rubbed upon cams, slides, gears, differentials, and other moving parts, chains, sprockets, etc. A chain treated with graphite occasionally will run dry but silent and dirt will not stick. It is also excellent as a coating for any threaded nut or bolt, as it permits easy insertion and at the same time easy removal. It is often used upon spark plugs before they are

screwed into their socket, and insures absolutely tight joints.

282. **Grease.**—There seems to be no one lubricant that is best in all places. In some respects grease has a decided advantage over oil. It stays in place better for one thing and, if a surplus happens to be introduced, instead of running down the outside of the boxings, it piles up in high collars on each side of the bearing and shuts off the entrance of dirt and grit.

Oil is not heavy enough in body to protect the shaft from any real abrading substance which happens to get into the bearing, while grease is. It also acts as a cushion, and makes gears run more quietly, and of course with less strain and friction; hence they are not so liable to chip when going into mesh. Grease is also best for differentials, and in places where drip is objectionable it is of special value. Mixed with graphite it is one of the very best lubricants known for gear wheels.

283. **Foolish Economy.**—Friction and actual abuse are the two things which above all others make machinery expensive, and it is certainly foolish economy to cheapen the one thing with which we are able in some measure to overcome this expense. Some one has said that lubrication is cheaper than the cheapest machinery is, and some one else that it is the cheapest of repairs. Both of these statements are true. Both should be committed to memory by every owner of machinery, and should be repeated daily, especially if that machine is a gasoline engine. When we consider the tremendous strain of pressure, heat and speed that is put upon this one bit of mechanism all at the same time, it seems wonderful that any thing made with human hands could endure it and survive. Certainly we who are benefitted should so far co-

operate with our little assistant as to furnish the very best supplies the market affords. After all, the difference between the price of worthless and of the best oil is but a few cents; not so great but we may most of us make it up in cleanlier habits and greater care in the use of the oil can. Much of the trouble experienced with the first crude gasoline engines, it has been discovered, lay in faulty lubrication—faults of the world's knowledge. When we take into consideration the fact that our more perfected methods of getting the oil we use to the very spot where it is needed have effected a wonderful saving in the quantity of oil used, we surely have no possible excuse for using any but the very best lubricants, be they oil or graphite, or grease, that the market will supply.

284. **Ten Lubricating Commandments.**—The oil that rolls out of the exhaust in the form of smoke is not a lubricating expense.

It is the small crystal of grit that plugs the feed pipe; not the large one that cannot get in.

Some engine owners seem to think that the best way to oil an engine is by the absorption system, through the pores of the frame. Don't try it.

Fill all the large oil holes up with woolen yarn instead of hay-seed.

Too much oil is a little better than not enough and a great deal better than a seized piston.

Don't forget the bearings; the lower as well as the upper half.

Kerosene or gasoline will carry oil into places where it would not otherwise go. Be sure that it gets there, if it is needed.

The best oil is usually the thinnest that will stay in place and do its work.

Proper lubricants insure against many cylinder troubles.

There is only a few cents difference in the first cost of a good and poor lubricant. The later difference may be many dollars.

CHAPTER XIII.

ELIMINATION OF ENGINE TROUBLES.

285. **Classified Trouble.**—Even our troubles may be classified if we look after them with sufficient system; and system is the one thing which above everything else it is the writer's wish to urge in this unlucky thirteenth chapter.

286. **Starting Troubles.**—Gasoline engine troubles include those numerous ailments, little and big, any one of which may prevent the engine from starting at all or with enough real life to keep it in motion until we have a chance to come upon our second class of difficulties, or operating troubles.

287. **Operating Troubles.**—By this we mean the various matters which, while they permit us to start the engine and keep it going, compel us to face some more or less disagreeable behavior which is not normal and which we wish to discontinue.

288. **Transmission Troubles.**—The engine itself may operate without fault, and still, because of some difficulty we may have in transforming its energy into useful work, we may be able to accomplish a desired task with it only through the unreasonable waste of personal effort, or else not at all.

289. **Energy Troubles.**—It is not so very uncommon for an engine when out of repair to run empty with as much seeming willingness as usual and still not develop enough energy to carry it along when hitched to a load.

290. **Irregular Troubles.**—Some troubles come to us out of conditions from which we might expect the very results we get as soon as our attention is called to them. There are, however, occasional surprises for which we are not prepared, and perhaps cannot at the time account; the irregular things that do not happen very often, and for which the usual list of ready made remedies will not avail. To all of these classes we will now give a few moments' attention.

291. **The Origin of Most Trouble.**—When we come to look at the matter fairly most of our gasoline engine troubles come from one of two sources, the things we forget, and the things we don't know. The frozen water jacket is not one of the inevitable results of gas engine management. Usually it troubles us only once at the first of the freezing season before draining the pipes becomes a fixed habit. So it is with nearly all trouble; something that doesn't often go wrong gives us a surprise, or else some part of the engine that has been so completely self-attending that we have never given it any thought springs something upon us that we did not previously know.

292. **The First Thing to Do.**—The very first thing to get when trouble comes is a firm grasp of the idea that there is a reason. The engine ran all right in normal condition. If it fails later on it is because that normal condition has been disturbed. The reason may be hard to find, but there is one, and nothing else is to be done until that reason is hunted out. Above everything else, don't get excited; nothing serious is going to happen if we keep our nerve. It isn't like having something go wrong with a steam boiler and a full head of steam and heavy fire behind it. While we are studying the situation over the gasoline engine is just a harmless piece of iron, no more

dangerous than the anvil beside it; so there is all the reason in the world for keeping it just a piece of iron until we can begin to understand the nature of the trouble.

It's a pretty good idea, first of all, to go over the simpler things that we sometimes forget, or are careless about because they are simple. It does not take long to investigate these, and it is surprising how many gasoline engine experts have been called out when the gasoline tank needed refilling or the engineer had forgotten to close the switch. Look first of all to the tank. If it is full, notice whether a flying newspaper or even a dead leaf may not have closed the air entrance, and so shut off the oxygen. While looking at the carburetor better notice, too, whether the gasoline is coming over. Maybe the pipe is clogged. A good way to test this is to open the switch, so there can be no ignition, then have some one crank the engine and stand directly back of the exhaust. If getting its supply of fuel, and the valves are working as they should, a strong scent of gasoline is noticeable in the discharge. If the engine is water cooled notice whether it has been overheating. Even if no ice is in the jacket pipes are prone to freeze before the heavier body of water is affected.

293. **When It Proves to Be Real Trouble.**—Once convinced that none of the little outside slips of memory are to blame, we are ready to go after the difficulty in the interior of the engine. Other things being equal, it is always best to investigate the simplest thing first, though of course we ought to modify this so as to first catch that which we have some reasonable excuse for thinking may be wrong. Whatever wrenches, pliers and other tools we have that we are at all likely to need should be laid out

in convenient reach as there is nothing more disturbing to the puzzled machinist than having to spend half his mental energy in finding things. A good assistant is a great help in this, while a poor one is worse than a wrench without a handle.

294. **Test with System.**—In no part of engine management is system more an assistance than in the hunting of trouble. On no account permit in yourself or any one else the habit of testing a part here, another there and another over on the other side. After the first cursory glance over the entire engine for some superficial difficulty, the most rigid attention to system is surprisingly helpful, even a poor system being better than none at all. As 60 per cent. of all real engine troubles lie in some part of the ignition system that is the most logical place for us to go.

295. **A Few Simple Questions.**—To avoid the possibility of confusion, let us take one thing at a time and think it over a little before beginning to take things apart. With the switch open, let some one hand crank the engine slowly and study each stroke by itself.

Is the suction stroke all right? Does the intake valve appear to be opening as it should, and does it appear to close soon after the end of the stroke? If so, step back of the exhaust and let the cranking continue till the cylinder is scavenged out; then notice whether the customary fumes of gasoline vapor are coming over. If not, suspect the carburetor or the intake system somewhere, and test in detail. If so, continue the cranking and study the compression stroke.

Is there as much resistance to the piston as there should be? The compression in a five-horse engine should be just a little too much for an ordinary man to crank against without opening the relief cock. If it

fails to put up that sort of a fight look for external leaks first, around the base of the spark plug, the valves, the joint between the cylinder and its head if detachable, or the piston rings. Somewhere a hissing may be heard. If at the open end of the cylinder the rings are leaking. If the hissing is some place about the other end, coat all the places suspected with soapy water or oil, and watch for bubbles. If the compression is good, try out the power stroke. As most of the functions of that can only be studied from within, assume them to be properly performed, while strongly suspecting that they are not, and pass on to the exhaust stroke long enough to watch the working of the valve.

We have now found out that the fuel is being delivered and compressed, that the cylinder is being cleared of burned gases. Is the charge really being exploded? Let us close the switch and see. If so, is it on time? If it isn't, our interview is with the timer. If it doesn't explode at all there is something wrong with the spark, its formation, transmission or delivery.

296. Protecting the Hands.—The current from a four to six cell battery, which is about what most farm engines use, is not at all dangerous, and only moderately painful; still there are people whose nerves will be so affected by a few shocks that it may trouble them, so it is best to put on a pair of rubber gloves. This insulates the hands. Rubber boots or even a dry board is usually sufficient, or any other insulating substance interposed between the person and the ground; still one may have occasion, while working with both hands, to connect himself into a circuit through the iron frame, so the gloves are best. They are not expensive are so pliable that they do not interfere with

the work, and a pair used only for engine repair work, if kept free from oil, will last a long time.

297. Testing the Electric System.—Before making any internal investigation notice whether all the wires are fast on the binding posts, and if the latter are screwed up tightly enough to insure a perfect contact with the metal. If there is a loose wire end the trouble is found. Next, release the wire running to the spark plug by turning off the screw cap, and, holding the point of the wire near the engine frame but not quite touching; have an assistant close the switch and crank the wheel. If a fat, yellow spark jumps the gap between the wire and frame there is probably nothing wrong with the electric system unless it is in the plug or the timing; but if no spark appears or if it is of a pale color the difficulty is in all probability between that point and the battery. Care must be taken not to force the spark over too wide a gap or the insulation of the coil may be broken down and a serious repair bill engendered. For the inexperienced, less than an eighth of an inch gap should be used.

298. If the Spark Is Good.—If the spark seems strong remove the spark plug from the cylinder and note whether the gap between the points has gotten closed up with carbon deposit or if the metal is badly corroded. Clean the points thoroughly and also wipe the porcelain clean. It is just possible that the insulation of the plug may have been broken down. Test this by replacing the wire terminal, screwing down the cap and having the engine cranked. If the resulting spark is good, the trouble is in some other part of the engine; if much weaker than that which passed between the wire and the frame, the plug is faulty; if about the same, but weak, some other part of the ignition system is at fault. These directions

have been written with the jump spark system in mind, but apply equally to the make and break system.

299. **A Poor Spark.**—If the spark is poor or does not appear at all we will follow the cable carefully back from the plug to its other terminal, noting par-

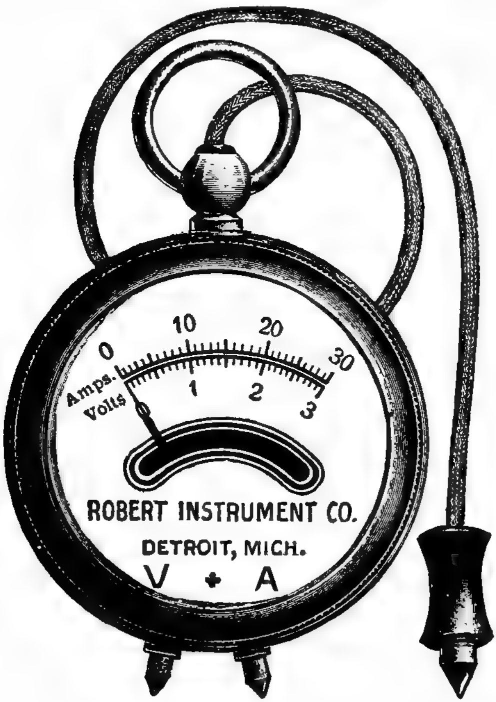


FIG. 77.—Pocket Size Battery Testing Gauge Indicates Either Volts or Amperes.

ticularly whether there are any points in it which indicate a broken wire under the covering. If there are none, see that the terminals are free from grease and with good contacts under the binding posts.

300. **Testing the Batteries.**—Beginning at the other

end of the system, we will now find out whether we have anything that will make a spark. Let us see whether all of the battery wires are properly connected, whether any are broken, if all terminals are clean and the contact good, or if there are any signs of a short-circuit in them. Next disconnect both terminal wires and test the reading with the ammeter; then test each cell separately, at the same time watching for one coated on outside of cup with white crystals. If one is weak, remove it, as it will run the others down rapidly.

If an ammeter is not at hand for this testing, the same results may be obtained by bringing the bare ends of two wires attached to the battery terminals into contact and then pulling apart. Each cell can be tested separately in this way, although, of course, the intensity of the resulting spark can only be estimated by its color.

301. **Testing the Coil.**—We have now reason to believe that a good spark is being delivered to the coil; that is, after we have seen that these connections are all right. It still remains to test the coil. If it is receiving a good current it is either delivering a good one to the secondary cable or else is wasting it through some short-circuit or broken down insulation.

Remove the secondary cable from the coil terminal and substitute a short wire from the end of which an air gap may be formed with any primary or low-tension post. If, with a gap of about 1/8 inch, a good white spark is delivered, the wire may be removed and the secondary cable replaced. But if the coil fails to deliver the spark, a readjustment of the platinum contacts (see that they are clean) may help matters. Loosen the screw that holds them slightly and then

tighten a little at a time and test. Then look to the timer and see that the inside spring is not broken. If all is found right and there is still no spark we may be pretty certain that the coil is burned out; that is, that somewhere within that winding of wire the insulation has given way and is permitting the current to short-circuit and be wasted. It is useless for the novice to attempt to remedy this, or, in most instances, for the local repair shop, either. The coil should then be removed from the engine and sent back to the factory where it was made or to one of its branches. Except from abuse this very seldom happens. Exposure to moisture, however, will in time rot out the insulation while an over-resistance placed in the path of the current, such as a wider gap than the coil is made for, or poor contact of the terminal wires through careless connections or greasy terminals, may cause the spark to break through the insulation in its effort to find an easier path.

If spark from coil is intermittent, examine the platinum points for pitting and, if found, smooth them down with a fine file or, better still, an oil stone.

If the spark is uniformly weak there may be a broken down condenser which the shop had better replace.

302. **A Faulty Magneto.**—If the spark is uniformly weak in the case of a magneto the field magnets need remagnetizing or else the armature winding is burned out. In either case the magneto must be returned to the shop.

Irregular firing of the magneto may be due to the incorrect working of the contact breaker. This can be determined by swinging the flat spring (numbered 119 in cut) aside, taking off the end cap (117) and tightening up the screw at 2 (see cut No. 45). Also

tighten screw at 5 and 6 and the steel segments at 21. Examine platinum points and remove any oil or grease. The contact breaker can be removed by means of screw at No. 2 but any further dismantling of the magneto by the novice is useless and should not be undertaken.

Aside from dirty or wet connections or a slight displacement of the contact points, it is not once in a hundred times that any trouble will be found with the coil or magneto; indeed, the trouble here is so infrequent that it sometimes is overlooked because one is likely to forget between times that any trouble can occur here. Always, before condemning either, be absolutely sure that all connecting wires are insulated and that the terminal connections are complete. A loose binding nut due to a stripped thread, or even dirty contacts, may be enough to interrupt the current.

Spark plugs, it is well to remember, may short-circuit an electric current when hot and not when cold; also they sometimes fail to produce a spark properly when in place in the cylinder although they may do so when removed from it.

303. **A Good Spark.**—It may be well to describe what a good hot spark looks like and what some of its feeble imitations are.

A white or blue-white compact spark is always a good hot one. If it shows red it is weak. If divided into little tongues of flame, look for short-circuits. If pale and rather greenish the spark is weak. A short, fat, yellow spark can always be trusted.

304. **Where the Shock is Felt.**—In making the examination of the ignition system one may notice that the primary circuit causes no serious inconvenience when so handled that a shock is felt, and that it is always the secondary currents that have the sting in

them. The winding in the induction coil is for the purpose of intensifying the current of the secondary or high tension system. How well this is done may be surmised from the fact: that, while a battery of six ordinary dry cells produces a current of about nine volts, it requires something like 4,000 volts to produce a ¼-inch spark.

305. **A Few Ignition Facts.**—Faults of insulation, that is, short-circuits, are more important along the transmission line than are dirty plug points unless there is a complete bridge between the latter for the current to cross.

The positive battery terminal, the carbon, should always be connected with the coil, in the jump spark system.

With the wiring all connected up, the absence of the characteristic buzz at the coil box when the engine wheel is turned over is evidence that something is wrong with the system.

Six volts and one-half ampere of current should be ample to operate a good coil. If set to use more, it only runs the battery down that much faster. Five cells of dry battery ought to give this.

Excessive current or disconnected secondary wires, if the cells are fresh and strong, may cause the current to seek a short cut in the coil and break down the insulation.

The make and break contact points gradually fuse and shorten with use until presently the time comes when they will no longer reach to complete the circuit; then the engine refuses to fire at all, until they are lengthened.

If one cylinder of a multi-cylinder engine continually misfires while the others do not, suspect the plug.

If ignition fails suddenly it is a pretty good indica-

tion that there is a short-circuit, probably in the wires or coil.

Often a broken porcelain in the spark plug causes the short-circuit; and the break is often due to screwing the plug into its socket too tightly. Never use a large wrench for this. The hand is often enough though, with the standard ½-inch pipe thread which is tapering, more leverage may be needed. A plug that is moderately tight when cold may become so tight when heated that the porcelain will break.

306. **A Suspected Timer.**—Notice if there are any worn parts about the timer. It must be absolutely accurate, and there is nothing accurate about worn parts. The ground wire circuit should be looked after, lest the timer lubricants may be interfering with it. Clean out all grease, gum and oil, and put in new castor oil or light sewing machine oil.

Open pet cock in top of cylinder and turn engine over by hand with switch closed and fuel shut off. The spark should come just after the escaping air stops hissing. This is not a very delicate test but it is sufficiently accurate to prove whether the timer has slipped.

307. **Other Troubles.**—With a good spark at the plug and the gasoline mixture coming over all right some of the other reasons for a balky engine are sticking valves, and water in the gasoline. The first of these may be detected by watching the valve stems while the engine is being cranked; the second, by testing the gasoline.

Often, too, the novice, in his anxiety to start well, is overzealous in supplying gasoline to the carburetor, and floods it so that too rich a mixture comes over; or the air inlet may be too small, or obstructed. On the other hand, there may be an excess of air because

of a leak somewhere along the intake pipe or on account of a grain of dirt in the spray nozzle. Remember that air is sure to occupy all space not taken up with gasoline vapor, and, if anything cuts down the supply of the latter, there is certain to be an excess of air.

308. **When the Engine Starts.**—It is generally useless to continue cranking the engine that refuses to go with the first half dozen turns. That is more than enough to overcome all the little ordinary causes of hesitation. Let us suppose the engine starts off nicely and takes us along to our next counterful of troubles—operating difficulties.

309. **Lack of Power.**—Many an engine will run nicely empty, and still balk if asked to take on even a moderate load. Almost the same list of questions may be asked again that were, when it refused to start, although the answers may be different.

1st. What about the mixture; is it right?

This question can only be answered by experimenting a little. Increase the supply of gasoline until black smoke appears in the exhaust, then gradually cut off, and watch the engine. When it begins to show more power, continue cutting down the gasoline until the explosions begin to lack regularity and vigor, then increase until at their strongest. In the same manner, open and cut off the supply of air until satisfied that there is nothing wrong with the mixture.

2nd. How about the compression?

This can best be studied before the engine starts, so, after having previously watched it so closely, we can now afford to take it for granted for the time.

3rd. All that remains to study about the ignition is to notice whether the timing is in harmony with the work and the fuel; whether the explosions come at

the right moment of revolution, and if about the right proportion are missed. Running under full load, a miss of one explosion in eight is a very fair performance; and running under light load, three misses between each fire is not bad. A short time studying these symptoms sometimes accomplishes more in the right direction than several hours of dismantling and reassembling.

4th. The exhaust should next be studied; whether the valve is opening fully and at the right time or if it is closing as it should. It is always barely possible that there is not sufficient vent, owing to an accumulation of carbon or lime. Never forget, either, the importance of the symptoms which may be found here; that black smoke means too much fuel or, rather, faulty combustion; blue smoke, too much lubricating oil, and white smoke, too much oil or water or oil of an inferior quality. While only a matter of extravagant expense in itself, this represents a condition in the interior of the cylinder which is daily bringing us nearer to the time when pre-ignition, broken or bent crank shafts and similar troubles will be taking our attention.

5th. Is the power impulse delivered to the crank shaft, or is it distributed pretty evenly through loose piston rings, worn bearings and connections, or wasted in overcoming useless friction in the shaft or bearings out of line? It is not uncommon to see a large proportion of the power after it is produced dissipated in some such useless way.

6th. Is the lubrication what it should be at all points? Faulty lubrication always means needless friction, which is one of the worst machine and energy consumers in the world. Often a few drops of oil more per minute will add 10 to 20% to the available

power by preventing the cutting of a shaft. With the gravity system, 8 to 10 drops per minute are required by the moderate size farm engine. This number, on account of the larger drops, should be reduced to 5 or 6 per minute if force feed is used, and will have to be increased a little if the engine is air—instead of water-cooled—on account of the higher temperature.

Three or four drops per minute for the crank shaft bearings, if with gravity feed, should be enough, the exact amount being of course determined by appearances in each individual case.

When we consider each of these half-dozen matters by itself we are apt to get a more comprehensive view of things than when we try to scatter our attention over too much territory at once.

One other cause for lack of power may come up in the cooling system. If that fails for any reason the engine heats, the oil burns out, the rings leak compression, and the gas may expand so in the hot chamber that less than a full charge is inhaled each time. Any or all of these might easily affect the power of the engine appreciably.

310. **Overheating.**—When an engine shows a tendency to overheat under load, the job in hand may sometimes be completed by giving it a little extra time and an occasional rest. A perfectly working engine ought to run under load continuously from one week's end to the other if necessary; but nearly all farm work may be adapted without great loss to short runs in an emergency, and by that means the engine kept upon the job without injury.

311. **Causes of Overheating.**—Overheating may be the result of faulty construction; then, perhaps it cannot be overcome. It may be due to overload, or to some other form of mismanagement. Dirt may have

clogged the water or the lubrication system in some pipe or valve. The exhaust valve may not lift enough or the exhaust port be too small; or the same result may come under a different name from back pressure in the muffler. An overdose of gasoline will cause excess heat and a late spark is specially troublesome as a heat producer and power extinguisher as well. Nearly all of these difficulties are registered in the discharge from the exhaust.

312. **Other Causes.**—An engine that has once been tested on a full load without overheating has eliminated from the possible causes faulty construction. What has been done can be done again. With a water-cooled engine the trouble, if it lies there at all, is purely mechanical, similar to any of the corresponding troubles that come to any pump. If the engine is air cooled there is the possibility of a displaced fan-blade, or the current may not be directed against the air jacket around the cylinder; or very possibly some partition near by is interfering with the ready air supply.

313. **Cooling a Hot Engine.**—If the trouble is not noticed until after the engine is very hot it may not be safe to start up the water circulation suddenly until the iron has had a chance to cool. The load should be removed at once, but if the engine is seen to drag it may be unsafe to shut down entirely, or a seized piston may result. If such is the case, keep running slowly, with the greatest spark advance, but with the fuel cut almost off, until it has a chance to cool so lubrication becomes effective again. Watch the temperature carefully during the continuance of these more favorable conditions; then, as soon as safe, start up the cooling circulation.

314. **Speed Variations.**—A certain amount of speed

variation is to be expected on account of the power impulses coming in the shape of sudden blows rather than by steady impact. This tendency is very noticeable in the running of an electric generator direct from a single-cylinder four-cycle engine, which is not provided with a special balance wheel. These variations are, however, normal within certain limits, after which they indicate some fault in the engine or its management.

315. **Suspecting the Governor.**—Racing and then dying way below normal may be due to a disarranged governor or to one the springs of which are too stiff to respond as readily as they should. If the charges are being admitted and exploded regularly, do not blame the governor. If several charges are exploded without missing when the engine runs way above normal and then a number are missed after it has dropped below, the chances are that some part of the governor is working too hard, either on account of a stiff spring, or a rough casting, or some other source of excess friction.

316. **A Lazy Engine.**—A lazy engine is pretty certain to have a leak in the valves or the piston rings or the spark plug, unless the ignition is at fault. In a well timed engine good compression may be considered a result and, if it fails, a leak is the cause. If every charge under the extreme load the engine will carry is being fired regularly the spark is all right and nothing is left to suspect very seriously except the compression. If the engine still runs too slow when firing every charge and the compression seems all right, suspect overload. Throw off a part of the load and note whether speed is increased so that the governor begins cutting out. If not, there is some other cause, and it is findable. The day of spooks

and witchery has gone by. Sometimes a leak occurs from the water jacket, which admits water or steam into the combustion chamber. The water-cooling system and the lubrication should be looked after at once, as there may be a threatened seizing of the piston. Heated bearings at the crank shaft, or even in some of the driven machinery, may slow down the engine; or there may be trouble with the mixture. The improper admission of air will cause irregular speed. This is a trouble that must never be allowed to continue without hunting out the cause. The tightening of worn bearings may in time affect the alignment enough to cause excessive friction and heating. The most sensitive engine and the best, when conditions are normal, may be the most affected by this.

317. **Pre-ignition.**—Pre-ignition, fortunately for the crank shaft and connecting mechanism, announces itself with so much vigor that it is not apt to be long neglected, especially by the novice who meets with it for the first time. It may be caused by advancing the spark too far, so that the power impulse is hurled against the piston before it has quite finished its compression stroke; then it is driven violently back against its own stored energy. Anything like burning soot or failure of the cooling system, or anything which permits the temperature of the combustion chamber to reach the igniting point of gasoline, may cause it, or an attempt to run on advanced spark when an excessive load has crowded the speed of the engine below the point where an advanced spark can be used. It differs from back-firing, which it closely resembles, and with which it is often confused, in that pre-ignition is the result of some igniting influence exerted too early in the engine cycle, while back-firing may and may not be. Often the latter is caused by a

faulty mixture which burns so slowly that the interior of the combustion chamber is still a mass of flames when the intake valve opens to receive its next charge; then the flame flashes back along the intake pipe, frequently to the carburetor; or a poorly fitting valve may not close sufficiently tight, and the flame rush back. Pre-ignition is accomplished in the cylinder, too; while back-firing takes place in the intake pipe, although its source may be in the cylinder.

318. **Misfiring.**—This occurs from any of several causes or a combination of them. The mixture may be faulty and fail to ignite, or some defect of the electric system may occasion a spark that is not hot enough. Weak batteries or faulty insulation or foul spark points, anything which tends to reduce the spark intensity, may bring about misfiring, especially at high speeds or if the timer happens to be slightly out of adjustment. Misfiring is perhaps more frequent than pre-ignition, but not so serious in its results. It wastes the charge and allows considerable speed fluctuation and slowing down of the engine, but it does not jeopardize the crank shaft and piston by hurling its energy directly against the energy already developed. Its effect is negative almost wholly, instead of a positive hindrance.

319. **Back-firing.**—This is one of the legitimate results of misfiring, which it very often follows, the unfired charge being trapped in the hot muffler and there fired into the open air. Perhaps its greatest harm is the consumption of good fuel without benefit, but there is perhaps no other engine prank more terrifying to the amateur, who first receives a fusillade of these startlingly sharp reports, especially if two or more charges happen to be delivered before either of them is ignited. If the mixture was too rich to burn

well in the cylinder it may, on being discharged into the presence of more air, become readily combustible. It also frequently occurs when the spark is being retarded before stopping the engine.

320. **Knocking.**—Knocking, rightly enough, sets the operator hunting for its cause—frequently quite in the wrong direction. Usually it means that something serious is wrong, such as a broken piston-pin, a worn cylinder, or worn connecting rod bearings. Bad lubrication or a piston threatening to seize are other possible causes that demand immediate and rapid attention. Occasionally a certain amount of knocking arises from a tardily fired charge or some less serious cause, but the occasions are so many where this can be taken as a most alarming symptom that no one should allow a knock to go uninvestigated.

321. **Pounding,** often classed with knocking, is only an aggravated form of the other in its manifestations, although it is usually caused by a pre-ignited charge being hurled against an ascending piston, and is generally due to an over-advanced spark.

322. **Outside Knocking.**—Knocking outside the cylinder is less difficult to locate, though it demands immediate attention. Usually it means some purely mechanical trouble about the crank shaft or its bearings, things not at all exclusive to the gasoline engine, and only coming to it with a little more severity because of the extra force that is behind the piston. Any loose shaft may occasion it more or less; also occasionally a cylinder loosened from its base.

323. **Summing up Common Troubles.**—In general terms, most of the distinctly characteristic gasoline engine troubles may be subdivided into four groups, as follows:

Faults of poor mixture, including carburetor faults, clogged pipes, cups, nozzles, screens, water in the gasoline, clogged valves and faulty air inlet.

Faults of poor ignition: Weak current, short-circuits, broken circuits, poor spark plugs, worn or dirty points, loose wires and poor connections, broken-down coil, poor timing, points too close or too far apart.

Poor compression: Leaky valves or piston rings, broken rings, faulty construction.

Poor delivery: Poor foundation, poor balance, undue friction, due to failure of cooling system or of lubrication, bearings untrue or out of alignment.

324. A Bit of Parting Advice.—Remember always that the best way to overcome gasoline engine troubles is to prevent them by taking in advance of the trouble the care that has to be given afterwards.

When trouble comes it is best, unless one really knows the cause from its nature, to look for something simple first, the empty tank, the corroded or the open switch, the disconnected wire.

Do not be too ready to meddle with things that are working all right. Carry the oil can and the cleaning rags around a little more, and leave the hammer and the monkey wrench alone unless it is certain they are really needed.

In making adjustments, especially of the carburetor, expect a few back-fires and have the room well ventilated, and a pail or two of sawdust handy in case of fire.

Above all, when things go wrong do not get excited. Take things cool all the time, but take them to pieces only when it is required. Remember, that there are a few hundred thousand gasoline engines doing good work in the hands of all kinds of people, and that the burden of blame before the engine can be condemned

is with the user. Barring accidents and long continued wear, the only trouble that ever comes to the engine comes through the operator; while the most frequent source of trouble is the fact that it is not understood.

CHAPTER XIV.

SELECTING AND OPERATING A GAS ENGINE.

325. **Selecting the Engine.**—Perhaps no mistake is more common among purchasers of the first gasoline engine than the determination to get the best, unless it is the effort to get the cheapest. There is no best for all purposes; nor can the most experienced engineer, after having tested different standard engines side by side for months, always decide which one he likes best even for his own use. Almost any engine will give entire satisfaction so long as everything runs well. When trouble comes the engine is apt to be criticized, whether it is to blame or not. The first step, then, in selecting a good engine, is to decide, not which is the best, but what particular place and work it is wanted for. The question must be answered wholly out of the farm, from the kind of work it is to do.

326. **Style Required.**—For stationary purposes, the horizontal engine requires more floor space than the upright, and is not so well adapted to high speed. Because of its broader base, it is firmer under a heavy belt pull than the upright, the piston and cylinder are more accessible, and it can be bolted more rigidly to its foundations. Its lower center of gravity, too, renders it more solid for portable purposes, and in most cases it will probably give the best results in larger than four or five H. P. sizes. For the smaller engines

intended specially for extreme portability, such as for doing the choring and hand work about the house and barn, the upright has the advantage of lighter weight for a given horse-power both on account of the lighter frame and because of its higher speed. They are also more economical in floor space, and in the smaller sizes seem to be preferred by purchasers and manufacturers alike. They have some advantage in the matter of friction, a more important consideration in the small than in the larger engine, where there is a greater likelihood of margin in power.

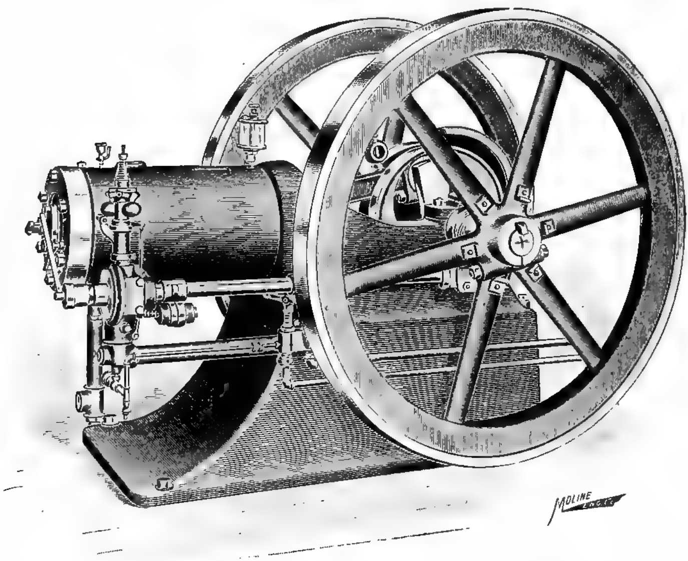


FIG. 78.—A Typical Horizontal Gasoline Engine.

327. The Best Size.—Every large or even moderate size farm needs two engines; one to do the heavier work like threshing, wood sawing, feed grinding, hay baling, etc., and another of from one to three horse-

power capacity for economical use in doing those numerous bits of drudgery that will save the man and woman. As a rule the man who buys a two- or three-horse engine now will put in more machinery in a year or two which may require more power; then he will probably regret having purchased so small an engine, but it is well for him to remember that he needs the small one worse than any other. For the heavier work he can, if he has to, get along with a hired engine, by adapting his heavier work to longer runs while the light engine is used perhaps several times every day in doing that back-breaking drudgery that is killing more men and women daily on the farm than anything else, but that would still be done in the old way in spite of the larger engine. Only the small power engine fits into this work with either economy or convenience. How many, for instance, have their buildings so arranged that it would be convenient or economical to use an eight or ten horse-power engine for pumping a couple of buckets of water or running the churn or the cream separator in a small family dairy for four or five cows? It is just such tasks as these, however, that are shortening the lives of hundreds of people on the farm; not the hard work so much as the unvarying hard drudgery.

The larger engine is usually purchased to save the farm team or to increase working capacity. It is the small engine that saves the man himself and his family. It will be used for a greater variety of work and more continuously than the larger engine, and the man himself will derive more direct benefits from it.

328. A Plea for the Small Engine.—It seems a little like advising a man regarding the size of his hat to tell him how large an engine he needs, the advice in both instances being the same:

get the size that fits the place. In farm work, though, the power required has an unusual range, and when one engine only is to be purchased the question seems to be one between a life of greater ease for both the farmer and his wife and family, or more extended field operations. Perhaps the best solution would be, say, a one or two horse-power engine for doing the every day farm drudgery, and a tractor for the farm. With the latter all such tasks as threshing, hay baling, wood cutting could be done, while at the same time the farmer and the housewife would be relieved of more real work and care through the engine of smaller size.

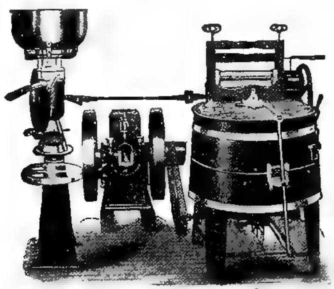


FIG. 79.—Easy Work for One and One-half Horse-power Gray Engine.

329.—Power Required for Various Farm Tasks.— For most of the work about the house and dairy a one or two horse-power engine will be ample. This will pump water in moderate quantities, separate the milk, churn, run the washing machine and wringer, spray the trees, and water the flower bed and garden, wash the windows, including those of the upper story, run a dish-washer or a vacuum sweeper, supply a modern bath room and all rooms of the house with running water, run the shop lathe, grindstone, emery

wheel, rip saw and small cut-off, wash buggies, whitewash the outbuildings, ten times faster than can be done by hand, sprinkle the lawn and a few other similar tasks that on the average farm are done at the price of aching backs or not at all; while in its spare time the same industrious little worker would, with the aid of a storage battery, accumulate enough electrical energy to give the farm buildings every night

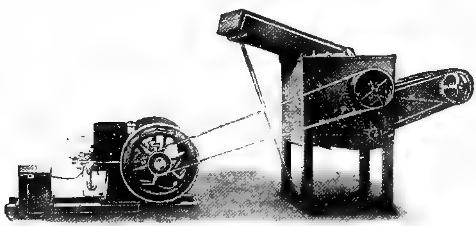


FIG. 80.—Corn Sheller Easily Operated by One Horse-power.

the same lighting conveniences enjoyed in the city residence at very little cost.

With a three to five H. P., the farm supply of wood could be sawed, the feed ground, hay and straw and stalks run through the cutter, grain and hay elevated, corn shelled, stock watered, and feed conveyors handled almost without hand work. An eight to ten horse-power would do practically all of the heavy work a stationary engine could be made to do upon a farm; such tasks as threshing, ensilage cutting, heavy grinding, corn husking. For a tractor, less than twelve horse would hardly be advisable, while for real satisfactory work at the plow and harrow on say a 200-acre farm, less than a twenty horse could not be advised. For smaller farms, tractors are now made of half that power that will do good work with the plow.

For attaching to the table or rear of machine for

binding grain, one of the light three H. P. now made is just the thing.

The power required depends a good deal on the condition of the material delivered to the machine, and a great deal more on the condition of the machine itself and of the engine; in other words, upon the care of the man who runs it. An engine that is big enough to do the work under most unfavorable conditions is,

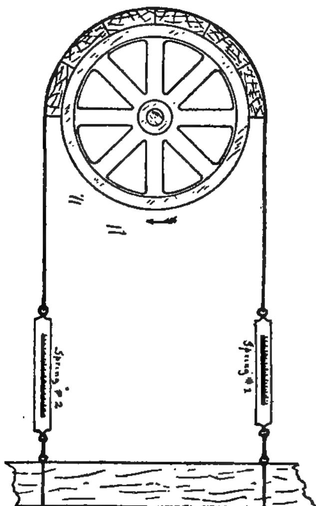


FIG. 81.—Simple Prony Brake Test.

of course, powerful enough for all the others, while one that will come up to the estimate only on the supposition that the material will be delivered in reasonably good shape may fail if the conditions are extremely bad.

There is, of course, danger of having a small engine overloaded in a short time if it is installed for general farm work, but for really saving the work and

sparing the health of the man and of his wife the small engine is ideal. It is also best to learn with; then it can be turned over to the boys to give them a new interest in farming, and a greater love for farm life than all the grindstones in the world could ever do unaided.

330. **What Horse-power Means.**—Horse-power is a somewhat arbitrary measure of energy, same as the

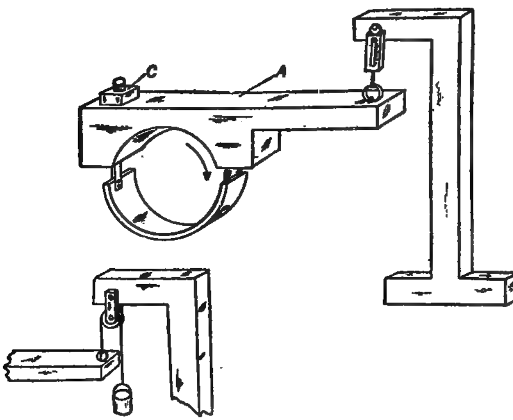


FIG. 82.—Another Type of Prony Brake.

foot or the mile is a measure of distance, though it is founded upon the more definite supposition that a fair load for an average horse would be the equivalent of a lift in one minute of 33,000 pounds a height of one foot. Since this unit of energy measure has been generally adopted as a standard, it is quite as accurate for purposes of comparison as though an actual horse had really been sent out to make the lifting test.

There are several kinds of horse-power in common use, however, or rather the standard of measurement is taken in several different ways, no two of which

mean exactly the same thing in amount of work actually done. As some machine men have been known to take advantage of this while others have certain standards of their own which are recognized generally in the measurement of certain kinds of energy, it is necessary to understand the comparative value of each in order to know what horse-power really means.

331. **Various Kinds of Horse-power Defined.**—**Actual** horse-power is the horse-power really developed, as proved by trial.

Brake horse-power is the power shown by a friction brake, the Prony brake being a favorite means of measuring. This is not scientifically accurate, but is near enough to answer all practical purposes. Brake horse-power represents the amount of working energy delivered at the belt.

Effective horse-power is the same as brake.

Indicated horse-power is the measure of the power developed in the cylinder, and is, of course, considerably in excess of the actual energy delivered. It is figured out by multiplying the area of the piston head in inches by the length of stroke in feet and the product first by the number of strokes per minute and then by the average effective pressure on the piston in pounds during each power stroke. The result, being in foot-pounds, is divided by 33,000 for the indicated horse-power. This is the measure upon which all formulæ for computing horse-power from piston area are based. The brake horse-power is equal to the indicated horse-power after we have subtracted from the latter the energy lost in friction, passive resistance, etc.

Nominal horse-power is defined as the horse-power calculated by a conventional and usually incorrect method of rating, as that based on the area of the

piston. It has so far lost any fixed meaning it ever may have had that it is of little importance excepting for the fact that it is still used as a commercial term for selling engines and confusing purchasers.

Tractive horse-power, owing to the rapid advancement of the traction engine, must now be admitted as a measure of engine efficiency. It represents the working energy delivered at the draw-bar; that is, the belt energy less whatever power is absorbed in the transmission gearing and the moving of its own weight. This usually amounts to between 50% and 60% of the brake horse-power, though one tractor now on the market claims a draw-bar energy of 80%.

332. Purchasing Horse-power.—With even the most careful attention to the relative meanings of these different ratings, purchasing horse-power is still somewhat an elastic operation. Many engines, for instance, which would operate for an hour or so at full rated capacity would by that time have become so hot that they could not be run at all. While most farm work is done on comparatively short runs, an engine should, none the less, be capable of maintaining for an indefinite period the full rated capacity for which it was sold. Probably no gasoline engine can develop more than 90% of its full possibilities and maintain it steadily for an entire day; hence it is necessary that an engine, to be honestly rated, have at least 10% reserve energy above its rating. Many of the best engine makers now supply this reserve; some of them, much more. In buying a cheap engine, though, or one from an unknown firm, it is well to keep this point in mind.

In justice to the gasoline engine before it is made to suffer from comparison with steam engine or actual horse ratings, we must give fair consideration to the subject of overload.

333. **The Overload as Affecting Ratings.**—An actual horse, under the lash of a brutal driver, can be made to develop several horse-power for a few minutes and then perhaps drop dead the next. A good steam engine, with an equal or heavier rated boiler at its highest rated pressure and a hot fire back of it, might be able to handle an overload of 40% or even 50% for a little while; then its capacity might drop below normal until steam was raised again unless in the meantime it had the assistance of a most strenuous and willing fireman.

The gasoline engine will take up the load that it was built to carry, less a small margin of under-rating allowed for unfavorable conditions, and will carry it constantly without any help from anyone. Beyond a small margin, no amount of urging will tempt it into increasing its exertions for even a short time; and abuse, if it has any effect at all, will probably retire it from the job. It has little reserve force back of it to draw on, and that little may be needed in overcoming the unfavorable conditions under which it may be working. The statement sometimes made that a steam engine will outpull a gasoline engine of the same rating is not true if the steam engine is worked in accordance with its permanent capacity, as the gasoline engine is. If a 15 horse-power boiler is set behind a 10 horse steam engine and steam raised to the point of blowing off, with the hottest of fires in the grates, and a good fireman doing his best to make it hotter, there is nothing to prevent the engine carrying an overload of several horse-power so long as the stored steam, the overcharge of fire, and the energy of the fireman hold out. The gasoline engine is self-contained, and depends upon itself. It has the strength for even a greater overload, for its shafts and bear-

ings are heavier, but it has no stored-up or borrowed energy to help it along. Whatever power it is required to use it develops and uses as the occasion requires, and, if it has no reserve power to help it along on overloads, neither has it a lot of reserved and wasted energy that was not used when an overload was not required. When we consider that overloading any engine is an unwarranted strain upon its structural strength, it would seem as if the engine that can be depended upon to develop its full rating steadily, without reserve power and without wasted power, has the best of the argument.

334. **The Question of Weight.**—The question of weight is more a problem of individual requirement than of engine necessity. There are places where, other things being equal, the heavy engine has a decided advantage. The massive frame absorbs considerable vibration and, like the heavy man on the lever, does some work to better advantage. There is also less strain on the engine because it is distributed through a greater mass of metal.

335. **Where the Light Engine Wins.**—On the other hand, one of the greatest arguments in favor of the gasoline engine is its supreme portability; and every pound of unnecessary weight added thereto is a departure from one of its great advantages. Weight alone is not always strength, not unless it is put where greater strength is needed than the light engine possesses. The old-fashioned binders were immensely heavier than the light steel structures of to-day, yet no one will say that they were as strong. Often the light machine indicates that it is a better balanced machine, more carefully planned out and less cumbered by unnecessary weight. Undoubtedly the heavy fly wheel and the corresponding machinery back of it

supply a greater amount of stored up energy; that is, the momentum is greater to carry the engine over sudden loads, or the idle strokes, but for much of the every-day farm work the light engine is decidedly preferable. For strictly stationary purposes the heavy engine bed and massive balance wheel absorb much of the destructive vibration, and add rigidity to the engine providing the weight is properly distributed. The present-day tendency though is toward lighter engines, not so much on account of the price as because of their greater convenience. Engines that weigh 200 pounds or less and develop three horse-power can be used in many places to far better advantage than a heavier engine could. In tractor engines weight has a greater significance, the tractive power of the wheels having a direct relation with the weight which holds them down.

336. **Simplicity.**—Always, when simplicity is obtained through a skillful placing of parts, the engine is more durable and easier managed, besides requiring less energy for its own propulsion. When it results from the omission of important details, we have to consider whether the result obtained will lose more in efficiency than we have gained in mechanical economy. The engine should have parts enough to insure good work, but those added for show alone should be discarded, and even the value of the conveniences should always be weighed against the extra parts they require. It never pays to curtail to a material degree the usefulness of the engine for the sake of saving a few extra parts or a little in price and weight. Neither should we choose an engine cumbered with a lot of attachments that are not needed for our work and that only render the task of taking care of the engine a little more complicated. On a farm where hired

help is kept we should always bear in mind that the engine ought to be so simple that the most inexperienced farm hand can soon learn to operate it under ordinary conditions, while it should not be beyond the boys of the farm to fathom its management under any conditions. So long as kept within the bounds of continued efficiency, simplicity means freedom from trouble for the novice.

337. **The Price.**—Price sometimes gets greater consideration than it deserves. We get about what we pay for, usually, but in the purchase of an engine it is well to consider whether we really need all that we get or whether some of the price is being expended upon things of negative value. Quality, experience in engine building, good workmanship, and good material are all worth paying for. Expensive clerks and salesmen, big commercial splurges, are not unless the increased sales they bring enable the manufacturer to give better quality on a closer margin of profit. Always it is the purchaser who has to pay the manufacturer's bills, but he can only judge of them to a limited extent, and when they represent a policy that is specially aggressive.

Continued improvements represent a progressive spirit. Excessive changes every season may represent designs that have not been working out right or experiments which may be more costly than beneficial.

It is a good idea for the prospective engine buyer to read and study the catalogues of a good many manufacturers, not only for the suggestion he will get in the selection of an engine for his purpose, but because in this way he will finally get at something like a normal price; then when an agent asks him much above or much below this figure he will be in a position to find out why. It is well, too, for everyone to

remember that the "terms" of 30 days' trial offered by many engine firms are of little practical value except possibly a means of determining whether a certain size is large enough to do the work required of it. So far as general engine merit is concerned, any engine that will run at all will run for thirty days without showing much wear. Almost any engine sent out can be made to run quite well by an expert, while a novice would hardly be accustomed enough to his engine in that length of time to give it a fair trial.

338. **Adaptability.**—This is of more importance than some phases of the price consideration or alluring "terms." The cream separator needs a steadier running engine than the hay work hoist or the pump requires. The light, air-cooled cylinder could stand work that was cut into one or two hour periods, and not be suitable for a steady pull under full load all day. There is a record of one engine that had not made good under certain conditions, that nevertheless, when nearly submerged in a cellarful of water, patiently pumped itself and the cellar dry, a feat that would have been too much for many a sturdier engine.

339. **Other Considerations.**—Repair economy is always a feature worth paying something for, and the engine made by a responsible house near home is worth several dollars more than one sent out by an institution about the stability of which nobody knows, and which at best is hundreds of miles away, with a heavy freight rate between. Other things being nearly equal, the engine with a local representative can be kept in working order better and cheaper than one that can never receive a supervising word from one of its own people.

Ease of adjustment is specially important on farms

where hired help is kept and engine experts hard to find.

Some engines save enough fuel in a season to make up for a few dollars difference in first cost. The purchase price is an investment; the upkeep, an expense. Sometimes it is a choice between the two. A pint of gasoline per horse-power hour is a liberal allowance of fuel for some engines, while others have been known to more than double this amount, while there are a few that can reduce it.

340. **Testing an Engine.**—Every engine sent out from the shops is supposed to have been tested, but shop conditions are very different from actual work in the field. A reasonable test should include the same character of work the engine will be used for, and under similar conditions. If wanted for electric light work and the plant has not yet been installed, hitch the engine to something that will show speed variations readily, and run it for several hours on a steady pull. Part of an engine's test should be under a full load and part of it at considerably less. A loaded engine sometimes develops characteristics such as heating, which it would not do running empty, but the loaded engine will be run as a rule at a lower percentage of fuel expenditure. Wood sawing is rather a trying test as the strain is so intermittent, but that will not bring out a propensity to heat. That requires a steady pull at full load.

341. **Being Fair with Engine and Agent.**—Be fair with the engine and the agent, though. A new engine is never in condition to stand the run without heating that it could after the bearings, rings and cylinder walls had seen a little service. It is not fair to put it to the last strain, nor to subject it to any strain which is not a part of regular work. The de-

liberate effort to stall the new engine or in some way force it to show a weakness that is not a part of its factory inheritance is neither good business nor good intelligence. If an expert is there to install the engine, do not have a big crew of hostile men and a lot of work piled up in his face. Plan to give him all the chance in the world to get the engine into good working order rather than to get a lot of wood sawed, or furnish amusement for the neighborhood. Do not undertake anything that will keep you too busy to receive and think about his instructions. Do not keep him too busy to give them. Have plenty of material handy for a reasonable test, with a man or two to assist him if he needs them. Let him do the testing, and the helpers all the other work, while you watch him and the engine. If you are sincere in wanting to buy an engine, you want it to be a success; give it a fair chance to be, and give yourself a fair chance to see how it can be made one. After he has had it working nicely for some time get him to shut down and watch you run it. Power and efficiency curves are worth a lot to the engine designer. An hour or so of practical field work with a practical man is worth a great deal more to you, and be sure the average expert will exert himself a great deal more to help you if you help him by being reasonable.

342. **When the Agent Does Not Come.**—Sometimes no agent or expert is sent. In that case the engine generally comes crated, and set up ready to run. The first thing to unpack is the instruction book; take it to the house and study it until the next day. In removing the crate, be careful with the hammer. Some parts of the engine are made to stand hard knocks; but learn which first. A half day spent in washing it off thoroughly with turpentine will be well spent

for two reasons. There will be more or less grit about it that may, if at once started, be drawn into the cylinder, so it really needs the thorough cleaning. Then as the work is done each part is likely to be located, studied and compared with the description in the instruction books. At the end (not the beginning) of that time would be most suitable for marking the timer and similar adjustments that are not already marked. After the cleaning is done, oil carefully and hand crank, again studying the different parts in motion.

Before starting under its own power, fasten securely to the floor or some solid foundation. No engine can do its best work while hopping around loosely. Run empty for balance of the day, and note carefully the exact consumption of gasoline and oil. Never start an engine standing over a spot where gasoline has been spilled. If the engine should race it might back-fire and cause trouble. After getting somewhat acquainted with it, turn off the gasoline, feed slowly until the place is found where it will develop its full power and where further reduction decreases it.

343. **Turning on the Load.**—Perhaps you have seen the claim that "the engine runs itself." After running it empty for a while, to prove that it does, it is time to find out what else it will run. Hitch it first to some empty machine and turn on the load gradually, watching closely. Let it carry a fair load then for several hours, but on the first sign of heating above normal, shut down. Once cutting begins, it is very hard to overcome. Do not condemn the engine for a little heating until paint and all roughness have been worn down. Above all, do not begin trying it out on overloads until the superfluous paint

is taken off, and your knowledge how to run it put on. Nothing is harder on an engine than to stall it down, as the advanced spark throws full force of the explosion against the engine for the last few strokes. Do not give it a taste of full load the first run. No skilled machinist would think of doing that with a new lathe or new machine of any kind. The first day he accomplishes little real work with it; just works it into harness gradually, and watches it too closely for any little troubles to have time for much work. If the troubles come he tries to help it overcome them. Often he does not allow it to carry a full load for two or three days. When giving the engine its first run, shut down frequently and examine, to see if it is heating beyond what it ought to and if the parts, particularly the cylinder, are being oiled. Watch all the bearings, and be careful that none of the nuts jar loose. Make no changes in the adjustments when running all right, but study out what you would do if this or that went wrong, and why, before it does go wrong; then try and find out from the instruction book or some one who knows whether you are right, and, if not, why not. Do not take the advice of any one as the last word in engine culture, though. The man who thinks he knows all there is to know about the management of engines would do well to wait a few days, for he has a lesson coming to him. If he realized that, he would think the other fellow might be like him and not trust too implicitly to all he said.

344. **The Outfit.**—When buying an engine some explicit understanding should be had as to what it includes. There are some outfits being advertised at a low price which include little but the bare engine. Tank, connections, pipe, batteries, spark plug, etc., have all to be bought afterwards. Some outfits in-

clude part of these but not a carburetor. Others include all that is necessary, even a magneto, belt pulley, and all connections ready to turn the wheel over and start. All of these matters should be arranged by agreement beforehand or they are likely to arrange a disagreement later on.

345. **Second-hand Engine.**—A second-hand engine is generally a bargain for buyer or seller; the question is, which? Anyone purchasing an engine so far removed from the dealer's guarantee is justified in asking a good many questions. Why is it being sold? If said to be "too light," just what did it fail to do, and what did it do? Look closely for wear at the bearings, particularly if a two-cycle; also to the connecting rod, and all the cams and their rollers. The bearings may be replaced with a little babbitt metal; the cams cannot be. Test the compression fully; and, if poor, try and make out whether the leak is at the spark plug or the rings. Hand crank for this test, and turn off all lubrication in order to find out whether it is the rings or the oil that is holding. Notice whether the valves are pitted or if they have been reground until they are almost buried in their seats. If the spark is a little weak test the connections and the coil; then the batteries. If the fault is here figure on an expense of about $1.50 to renew them. If the coil is wrong the cost may be several times as much. The cylinder and water jacket should be examined for cracks and the owner made to give a definite statement as to their condition. A crack cannot always be seen, but gasoline under pressure will find it. Paint may tell something about the age of an engine and how well it has been cared for; or it may be used fresh for the occasion to cover up defects. Which one the engine is a bargain for depends as much

upon the honesty of the seller and the practical knowledge of the buyer as upon the engine. It is always safe to remember that an expert will get good work out of any engine for some time if it will run at all, and that the owner is very likely to be something of an expert with his own engine.

346. **After Buying.**—Having purchased an engine of this sort, do not get discouraged at the first glimpse of trouble. Any engine may be thrown out of adjustment while being torn out and moved. A wire may be broken or rusted; many trifling things may happen. Don't take the word of the first agent that it is only fit for the junk pile. Let him show you why, if he wants to, but do not let him take it to pieces to show you. He may drop some valuable hint; his aim is to make a sale.

Write to the company who made it and get their catalogues, their directions, their advice. It may have to be sent to some shop for a general overhauling, or it may not be worth it; but be game until you find out. Don't condemn it until the minor repairs are made, if the case is hopeful. If it isn't, don't buy in the first place; but, having made the one investment, better put enough more with it to see it through. If the trouble is in the trimmings, the chances are it may be fixed up at a reasonable expense. If there is a cracked or oval cylinder to deal with, the case is dubious, though not hopeless.

347. **Oiling the Engine.**—So many of our engine troubles come to us because of things we forget, that any system which enables us to remember things will do much to eliminate our troubles. A regular system in starting and stopping the engine will save us many failures and not a few cracked water jackets in cold weather.

First, clean out oil holes from dirt and grit, and see that lubricators are all in place and filled. For starting the first time, open the cylinder lubricator and permit the oil to drip a short time, hand cranking the engine so as to get the inside of the cylinder, the piston and rings thoroughly oiled. Oil the balance of the engine same as any other machine, beginning at one side and making a clean sweep of it while going around. Take this occasion always to notice whether the valves are sticking or the governors and gearing all right.

348. **The Cooling System.**—See that the cocks are open along the water system and that the water is circulating through the pipes. Do not guess at this; be sure. Of course all drain cocks must be closed and there must be a supply of water in the tank. If the engine is air cooled notice that the fans are all in place. If the engine has been run, open drain cock in muffler pipe if one is there, and drain off any condensed water it contains.

349. **Retard the Spark.**—Of all directions, this is one of the most important, for upon its observance depends the operator's safety. Set the spark lever back as far as it will go, or follow whatever directions for spark retarding came with the engine. Perhaps more people have been injured by gasoline engines by reason of not observing this rule than from any other cause.

350. **The Carburetor.**—Open the cock between carburetor and fuel tank and depress the spindle to the float valve until a supply of the liquid comes over. See that the air intake is open. In cold weather it may be necessary to warm the tube or the intake.

351. **The Switch.**—Close the switch by bringing the lever down until it is pressed clear back into the

groove made to receive it. See that the metal is clean and the contact good.

352. **Starting the Engine.**—If the engine is small grasp the fly wheel rim with both hands, if crank is not used, and turn the wheel over, in most engines from left to right or **with** the hands of a watch. Release just as the compression has been overcome and the resistance begins to ease off. If the engine is too large to turn over by hand, a bar is sometimes used, but is rather dangerous for a novice. If there is a relief cock in end of cylinder, open this and crank until first explosion occurs, and then close at once; if not, the exhaust valve may be held up with a block tied to a string until the power stroke begins; then the block should be jerked out quickly. Usually the explosion will come with the first or second turn of the wheel. If not with the first, catch the rim as it comes around after being driven back by the compression and, with the momentum gained, try and keep it going over the next compression. Do not forget to release the hold at once when extreme of compression stroke is passed. If the spark does not come within the first half-dozen turns better stop and investigate, as something is wrong. Be careful always, while turning the wheel, that there are no projections to catch the clothing or strike the person. Never under any circumstances turn the wheel by setting a foot on the spoke.

353. **Just After Starting.**—As soon as possible after the engine has started shut off the cock on the gasoline line about a half, as the mixture, once the suction of the cylinder is established, would otherwise be so rich the engine would soon choke down and stop. Advance the spark gradually, as the engine picks up speed until it is running strong; then go back to the

gasoline supply and regulate the flow of air and gasoline as already described until just the right opening is found. By noting the position carefully, these adjustments can afterwards be made with very little trouble, although there is a little variation required under certain conditions.

If the engine should not start, don't blame the engine. Open the switch, shut off the lubricators and read your instruction book again.

354. **Getting up Power.**—Do not expect full power of any engine at once. Everything about it is cold. Sometimes in cold weather it will be found necessary to partly close the end of the air pipe while starting. In that case open again gradually as the engine warms up, until wide open. If the engine is new, a good deal of its power may have to be expended on itself for some time. If old and for some time in disuse, the cylinder walls may have become rusty and so retard it.

355. **Going After All the Power.**—A surprising number of people will select their engine with most critical regard for its economy in fuel for the power developed, and will then defeat their own object through carelessness in adjustment. Engines that are set level and on firm foundations will do more work and at less cost for fuel and less wear on the engine. Dirt, grit, floating dust, obstructions of any kind, have more or less effect, and that effect is always bad. In the first place it invariably means careless habits, and that is fatal to getting the full power out of the engine. Valves that are poorly regulated are wasting fuel and energy. The poor adjustments which might be made right as easily as wrong may overcome more than 30% of the engine energy sought after with so much care while making the selection. The man who,

after paying a round price for an engine of the highest efficiency, gets less result from it than one who buys a cheaper make, may have his ignorance of engines to excuse him at the start. If that ignorance continues, he has no excuse. He is to blame himself.

Dirt means anything out of place. Too much gasoline in the cylinder is dirt, and so is too much oil. Even the tools required to operate the engine may become rubbish by getting out of place. The most untidy engine room on earth may not contain so very much that its most up-to-date neighbor does not contain. The difference is only in the arrangement; in a carelessness that will be fatal to the working of an engine. Remember that whatever is worth doing at all is worth doing the right way, and whatever has to be done is worth doing well.

Some gasoline engine men will run their engine for months without learning more about its construction than they were obliged to learn the first day in order to run it at all. This speaks well for the engine but not for the man. A steam engine would in that time compel at least a speaking acquaintance with the man behind it, or quit work. Possibly the engineer would quit at the same instant. Some engine men, and not professionals either, can tell from the sound what the engine is doing; others are barely able to tell from the looks afterwards what it has done.

356. The Gospel of Attention.—Gasoline engines are often advertised to run without attention; that does not mean that reasonable care is injurious to them although they are often neglected on that account. A new engine, in particular, should be watched for loose nuts, loose bolts, tight or loose bearings. Very few things go wrong without some indications or symptoms that the observing attendant can read.

Not only does the engine need this close attention until thoroughly installed; the novice engineer needs it even more. The drill in close observation will be invaluable to him, and will serve him many times in getting out of trouble because of his familiarity with the exact performance of each part when all was working well. Reading instruction books may do much toward teaching him what to look for. Experience and observation alone will teach him how to make the most of what he sees.

After the engine and the engineer have been tried out and are fully acquainted with each other, close attention or at least continual attendance may not be necessary. The engine may often be left to itself for hours. In all machinery, however, there is always the possibility of something going wrong, and the true engineer will prefer to at least come within earshot of his engine occasionally. As a general thing the man who could leave his engine wholly to itself with the least risk is the one who would be last to do so.

357. **Importance of Letting Alone.**—The gospel of attention should include special instruction in the necessity of letting alone. When everything is going as it should go, further adjustment is work for the experienced engineer. The novice who begins to experiment is just beginning his troubles. Even worse than this, though, is a willingness to let someone else experiment. We should be alert for suggestions, but should use our own brains a while on the idea before using the latter on the engine. If the engine don't work, master it yourself or else get an expert; don't let someone else try experiments at your expense. Even an expert, if the agent for some other line, should not be trusted. He may be conscientious; he is sure to be prejudiced and to have less real personal inter-

est in fixing up your engine than he would have in fixing his own.

Whenever, in walking around an engine, one is tempted to take up a wrench and go to work on some questionable adjustment make it a rule to pick up a bit of waste instead and clean a wheel or brighten the trimmings. That rule alone, if rigidly adhered to, will save a vast amount of trouble, as will the other rule to never take up a wrench until there is use for it.

358. **Shutting Down.**—There should be a regular system of shutting down as well as of starting; then nothing will be forgotten. Shut off the water supply, if a water-cooled engine; shut off the gasoline, open the battery switch. Stop the engine so that all valves are closed, so there will be no communication between the inside of the cylinder and the open air. Remove the drive belt by running it from the fly wheel as the engine slows. Shut off the lubricators. If the weather requires it, drain the water pipes. Clean up all patches of grease and oil; put tools in their place. Leave everything in perfect order for beginning another day.

If intending to leave the engine idle for some time, inject a small quantity of kerosene into the cylinder. It will remove most of the carbon and still leave the oil glaze on the walls and piston and rings. Turn the engine over a few times by hand while introducing it, then drain out, until the oil comes fairly clear. If very bad, inject a pint and let stand for ten minutes, turning the engine enough to keep it agitated; then open tap and leave open for 24 hours or else prepare to leave the neighborhood when next the engine is started. A coating of vasoline on the valves will do much to protect them while the engine is standing idle.

359. **Things to Think About.**—It's always the

blunders that cost. Things that go right are inexpensive.

In the present age of well made engines, the only troubles that usually come to an engine, outside of disturbed adjustment through vibration, are due to ignorance, carelessness and natural wear. Of these three causes, the first two are most prolific of trouble, and both of them are directly in the hands of the man himself.

The driven as well as the driving machinery must be kept in order if we are to get full returns in power from our engine investment. Dull knives, worn cogs, and shafts out of line all destroy engine energy and waste both fuel and power.

An engine that will deliver 10 full horse-power per hour on a gallon of gasoline may barely develop power using the same amount, in other hands. The difference is neither due to engine nor to fuel, but to the men.

Sometimes we know what we are paying for our power, without knowing what power we are getting or what it is costing us per unit of useful energy.

The vital time with any machine is when it begins to wear out. Easy repairing sometimes determines the difference between continued service and the scrap pile.

When the engine balks, as it some day surely will, consider five things well; compression, fuel, timing, spark, insulation.

At all times bear in mind these four rules:

Use good oil, especially about the cylinder.

Draw off the water in frosty weather.

Do not feed too much gasoline.

Keep battery connections tight.

If you want to make a success of operating your

engine study the engine. If you want to become a neighborhood expert at it add to your course of study mechanics, heat, chemistry, electricity, good sense, and your own engine.

360. **Overhauling an Engine.**—If the cylinder heads are removable, remove them, if the operation is to be thorough. Place them in kerosene to soak while cleaning the cylinder. Note the nature of the deposits; whether the oil used has been what it should be.

Have valves in soaking. Clean and scrape the heads, especially at the joints, but do not break the surface glaze. The valves may be rubbed with fine emery cloth. Notice that the valve guides are not worn unevenly along the side, and whether the valve seats properly.

Let the timer alone until the setting as supplied by the factory has been unmistakably marked. This should always be done when the engine is new, before it has a chance to lose its adjustment. By using graphite on the nuts they go on much better and do not rust.

If the engine is a multiple cylinder do not mix the pistons, even though they are interchangeable. Do not even change the rings. Each wears to its own peculiar position. If made to scrape out a new one each time there will be lots of waste energy and waste engine. Each ring will seat best in its own groove.

Note carefully the wear on the gudgeon. There should be some side float but no shake. Worn pins are probably case-hardened and something is wrong. If the wear on pins or bushings is at the ends, the rod is out of line. If full length the bushings should be scraped to fit the new pin. Bearings that are bright all over should not be meddled with; but if in spots

only, scrape the spots down enough to ease them. Scrape out any score marks on pin or in shell, then rub with oil stone or emery stone and finish with fine emery cloth.

The crank shaft should be specially well inspected for signs of uneven wear or false alignment. Nothing is harder on an engine than to jerk a wabbly shaft around by means of a twisting piston.

Clean all the wiring terminals thoroughly with gasoline. The coils should be cleaned also, but always with a care for the insulation, which must be guarded from oil or water.

If possible blow steam from a steam boiler through all the fuel and water pipes. Do not leave them unconnected until dirt gets in again. Connect up at once.

If a magneto is used, take it over to the electric light station and have it fully tested with a generator and Ohm meter. Coat the winding with shellac after brushing out and cleaning the armature thoroughly. After the shellac is dry, varnish. Do not forget to clean the armature bearings and to see that the oil grooves are open. Spark plugs should be removed and cleaned, then coat the screw base with graphite and screw into place with the hand if possible, never with a large wrench. Spare plugs should be looked over at the same time, coated with mineral grease, and wrapped in waxed paper. Keep them dry as well as dry cells and spark coil.

Even the fuel tank should not be forgotten. Clean out and look for leaks. Disconnect the pipe and get rid of all rust and scale.

The muffler should be given a thorough cleaning and its load of soot entirely gotten rid of. There is nothing to be injured here; use kerosene, gasoline,

whatever keeps the dirt coming, until the liquid comes out clear.

Coat the battery terminals with vaseline if the engine is to remain idle for a while as a protection from acid.

361. **The Personal Hazard.**—Accidents to the person usually consist of burns about the hands and arms

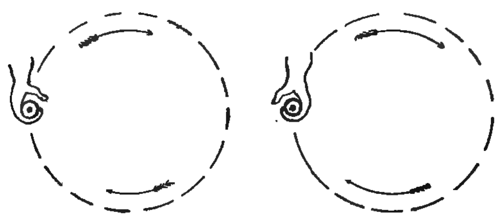


FIG. 83.—Correct and Incorrect Method of Cranking an Engine. Correct Method, Left Hand Used. In Case of Pre-ignition Handle Is Jerked Away from the Hand, Which Is Left Outside of Crank Circle. Incorrect Method, Uses Right Hand. Back Kick Will Either Drive Handle Against Hand or Leave Hand in Crank Circle. Result, Broken Arm or Wrist.

or about the face from flashes of gasoline at some unexpected time and place. Hot pipes, hot cylinders, a hot muffler, and the hot blast of the explosion itself are all about equally frequent offenders.

Injury to the eyes come from the muffler blast on account of after-firing or from back-firing to the carburetor.

Broken bones, broken noses and lost teeth are part of the general tribute levied by the fly wheel on the careless operator. To avoid these, never forget to retard the spark before cranking the engine.

The fans on an air motor give many a vicious bruise and cut.

A good many sore fingers have resulted from the hand-hold on the fly wheel being such that it brought

the fingers against the base or a projecting part, as a bolt head.

In starting with crank see that the crank is on and properly clutched; then, standing at the rear of the wheel with respect to its revolutions, grasp handle firmly and revolve over and from the person until compression is passed, then bring the handle around until turning against compression again. This ought to start the engine, when the clutch will be disengaged and the crank will drop from the wheel and remain in the hand. Use weight rather than strength in turning heavy engine over, then keep it rolling with the hands until the first impulse is felt.

Always suspect that there is a charge of unexploded gas in the cylinder. After the plug is removed this may be tested for with a lighted match, but keep hands and face away from all ports.

It is the business of every engine operator to protect all visitors he admits to the engine room. Danger signs are good, but not enough. The engine looks harmless and inviting, while the damage, if any, that it does is done in an instant.

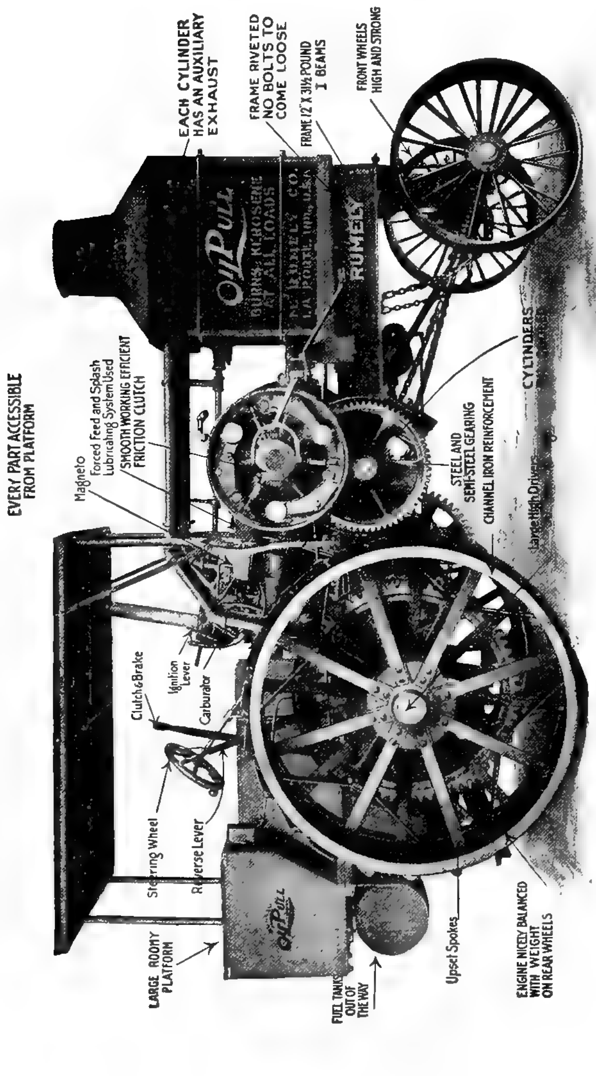


Fig. 84.—Assembly View of Oil Pull Gas Tractor, Showing Working Parts and Their Relation to Each Other.

CHAPTER XV.

THE TRACTION .ENGINE.

362. **Its Message to the World.**—The stationary gasoline engine has given its message to the world through farm and factory alike. The traction engine is to discharge its more important mission through the farm alone, a mission of threefold import at least, obtained as a direct result of accomplishments which are wholly its own.

1st. Through more extended operations.

2nd. Through more thorough work.

3rd. Through more timely work.

No mention is made here of the additional message to the farmer himself of cheaper labor, easier and pleasanter work, and more time to enjoy the luxuries of life, for which the tractor also furnishes the occasion.

363. **Its First Accomplishment.**—That the average man could not give true intensive culture to more than twenty-five acres of land has been the judgment of the best agricultural authorities for years, and even this amount would not be taxed to its utmost as fully as the man would. As the pressure for supplies becomes greater it has been more and more evident that the world cannot afford large farms skimmed over with careless culture; her one course, if she would keep her children all supplied with bread, is to increase the product of each acre by substituting twenty-five acre culture wherever the extensive methods are in use.

This means more men; more than she has to spare of the right kind. The problem was a perplexing one until the traction engine solved it by putting into the hands of one man the reins which control the work of twenty-five to fifty horses. Since the American farmer has not the time to properly till all the tillable land in the old way and there is no way of increasing the number, the time that was his has been increased by putting into his day the working energy of many men and teams.

364. **The Second Message.**—Usually the area of a single man's cultivated fields is increased at the expense of efficient work. The tractor is permitting him to do better work by giving him the power that is needed to run the most efficient machinery that can be made. The machine designer does not now have to limit his implements to machines that a team will handle; he is permitted to regard them from the standpoint of efficiency alone.

365. **And the Third.**—Only the farmer himself realizes how many times he has been forced to begin his plowing or seeding or harvesting before the ground or the crop was ready because at best the last part of the work would be delayed until later than it ought to be. With a 25-acre field to plow and fit for each man and team not less than twenty days would be required, of which perhaps ten would be within the time when the crop should be sowed and the ground in the best condition. During the first five days of the fitting the ground would be too wet to work well; during the last five the season would be getting late; but if the farm work was planned to the best mechanical advantage and the harvesting of the field to be done all at once as it should be, none of the field was sowed until all was fitted. Then how many of

us can tell the story of a large field almost ready for drill or planter when a three days' rain suspended operations for at least a week, made refitting necessary, and brought the planting almost hopelessly late? Not less than thirty per cent. of the world's output in farm crops—her possible output—is lost annually because of unseasonable seeding.

366. **What the Gasoline Tractor Is Doing.**—The small tractor for the 150 to 300-acre farms is plowing, fitting and seeding fifteen to twenty acres a day; an output to cover the entire farm it is intended for within the usual best seeding season, and enough to complete in one or two days the usual field of any one crop on a mixed farm of that size. Some of the farming moguls of the West are multiplying this output by three, and could, if run the full twenty-four hours, as they may be if required, have a couple of townships in growing crops at the end of the average seeding season.

367. **Special Appeals to the Farmer.**—Almost all kinds of soil, if worked in the proper condition, can be harrowed as soon as plowed more effectively than at any other time. Some farmers make it a rule to do this, though it necessitates extra teams or else a change of teams each working period from plow to harrow. The tractor can harrow as it plows. Once over and the work is finished, no matter what weather changes may come up.

Farmers differ greatly in their belief as to which is the best kind of harrow to use even for the same purpose and upon the same land, while many fields differ in patches in character of ground. The fact is, every harrow has its own distinct uses, and on most grounds a combination of several kinds would be a distinct advantage did it not necessitate driving over

the ground so many times. A good tractor will pull a number of these different harrows after it at the same time it plows the ground, and may be rigged to be the most effective of clod crushers with its own weight.

One objection to the thorough harrowing a field should really have is the trampling of the fresh plowed earth by the horses' feet. The tractor can be rigged to plow, harrow and seed all in one operation; or, if more harrowing is desired, the broad wheels do not throw nearly as much weight on one portion of the ground as the horse does and the rolling contact is less objectionable. If they are run twice over the field the thoroughness of the harrowing that can be done with them in the two operations would exceed perhaps a dozen times what could be done with horses, since several different kinds of harrows could be hauled at a time and supplement one another.

The plowing can be deeper than is done with teams and can be regulated more uniformly. A good many fields plowed by team power are from four to six inches deep, though perhaps their owners would be astonished to see their own furrows measured. The depth of a furrow is very deceptive to the eye. Eight to ten inches is the usual depth for tractor plowing, though a greater depth can be used if desired. This greater depth is of special benefit on those farms which have been plowed for years on the system of surface skinning until a hard, polished bottom of compressed soil has been established by the bottom of the plow, that cuts the roots of the plant off from nourishment below. By plowing a couple of inches deeper for a few years and then increasing the depths again, the depth of the seed bed can be gradually increased without bringing to the surface an excessive amount of hard-pan at any one time. The tractor can turn

this extra depth without torture and with astonishing uniformity. The thorough harrowing it can give while the earth is fresh will so completely pulverize this hard-pan and mix it with the other soil that it will not have any injurious effect, while it will help in the work of air and moisture-gathering and the seed bed will be deepened.

A horse cannot pull more than fifteen miles per day on an average, but a team must walk sixteen miles to plow two acres with a 12-inch furrow. The tractor will draw a gang of from two to twelve 14-inch plows two and a half or more miles per hour and will keep it up all day, without stopping to rest at the end of the furrow; then, by changing men, will keep it up all night.

The life of a horse is figured at about 10,000 working hours, but his maintenance is several times that. The working life of the tractor is at least twice as many hours, and its maintenance ceases when its work is done. The first cost is not so great as that of the horses it displaces.

Whether working or idle, the horse requires food, attention and shelter. All the idle engine wants is shelter—and work. This does not mean, however, that an engine should be kept idle. The man who makes his tractor pay the best is the one who manages to keep it busy the greatest proportion of the time.

The engine can be made an all the year around servant, something that can be said of very few other farm machines. Besides plowing, harrowing and seeding, it hauls binders, hay, and grain wagons both to the stack and to market, by almost a train load; threshes, grinds, and does all the other work a stationary engine can do, digs ditches, grades roads, rolls

meadows and grain fields, and hauls heavy loads of any kind. If the ordinary wagon load is to be conveyed, the tractor will do it. If some unusual work is to be done, such as the moving of a building, the tractor is ready with the power, and if, in the midst of its various tasks, night overtakes it, the headlight turns night into day ahead of it and guides it along. Twenty-four-hour stunts are not by any means rare in operating a tractor during the busy season.

The tractor, too, will take up its work at full capacity after a season of idleness without any coaxing or favoring while its muscles are being hardened. It is never out of condition.

One acre in five under cultivation is required to produce the food for the horses that supply the power to work the rest, a food product valued at $1,250,000,000 per annum, or the total income of 2,000,000 families. The tractor consumes nothing that could be made into food for the human family in any more direct way than through the tractor.

"There is no question," says a modern agricultural writer, "but that the crops on many farms might be doubled if a proper seed-bed were prepared and proper cultivation given; but on account of having a large acreage the work is hurriedly done; consequently only about half a crop is realized. One of the advantages of the small farm is that it is possible to do things in the proper way and at the proper time for growing a maximum crop." Profitable farming is now a power and implement problem. Power combines the intensive culture possible on the small farm with the economical management of the large one. In actual experiment a gain of two hundred per cent. which was made in the productiveness of a certain area, one hundred per cent. was found to be due to better plowing and

harrowing, fifty per cent. to better cultivation and the rest to better seed.

Sixty per cent. of the power used in raising wheat at the present time is expended in plowing; the shallow plowing method now so generally in vogue. For permanent culture deeper plowing is needed—and the farm world is power-short now. Horses increased fifty per cent. in numbers in the past ten years and one hundred and forty-three per cent. in price. The supply has not nearly kept step with the demand. Neither are horses able to adapt themselves so fully as the tractor to the wide range of utility represented between the slack and busy season on the farm. The horse force must be kept on an average 9,000 hours for every 1,000 hours of full service. Animals cannot respond quickly enough to the increased demands of the rush season unless they are kept in numbers which at most seasons of the year are entirely excessive. The tractor can be worked to its full capacity every day of the year if there is work to do, and without regard to excessive heat, flies or continuous hours. Weed-killing, in particular, can be done by plowing at a time when both the heat and the flies are a torture to horses. Engine culture, too, makes it possible to work land that because of its extreme refractoriness could not otherwise be put into tillable shape. It also makes it possible to avoid bad conditions by rushing the work through when weather and ground are the most favorable.

368. The Small Farm Tractor.—Because there are tractors now plowing and seeding a fair size farm complete between sunrise and sunset we are apt to forget its importance on the small farm; indeed, until quite recently the manufacturers have so far overlooked it that there was not a single small farm

FIG. 85.—Gas Tractor Insures 100 Per Cent. Gain in Production Through More Thorough Tillage of Soil.

tractor excepting those home-made affairs constructed out of old binder and mowing machine wheels. The success of these and the demand for something of a more finished and uniform design has forced the factories to take the matter up, and several of the late designs are intended (as some of them succeed in doing) to cater to the wants of the small farm. This demand has been more difficult to meet than that for the large farm, for the big tractor, working in large areas where there is ample room to turn, can be rigged with trailers, and its work may be of a more restricted nature, and still be profitable.

The small farm tractor must be furnished at a cost in keeping with the other equipments of the place. It must contain within itself a place for attaching and operating four or five plows, and it ought to be so constructed that it will thoroughly pulverize, roll and seed the strip it covers in one operation.

The seeding done, the tractor should be readily stripped of its tilling attachments and converted into a common power truck or general farm wagon, made so nearly a part of the load it conveys as to derive a part of its tractive force from the weight it is carrying. In a similar manner it should be converted into a manure spreader by attaching its tractor trucks in place of the customary front trucks of the regular machine. Again, in the meadow, the same tractor truck must be readily equipped with cutting bars, a complete power mower in itself.

One of the features which the user of the farm tractor should insist upon is greater efficiency as compared with any other sort of farm power. The tractor that does not do its work better as well as quicker has failed in its mission, and so have its manufacturers failed in theirs. The heavier weight, the smooth, broad

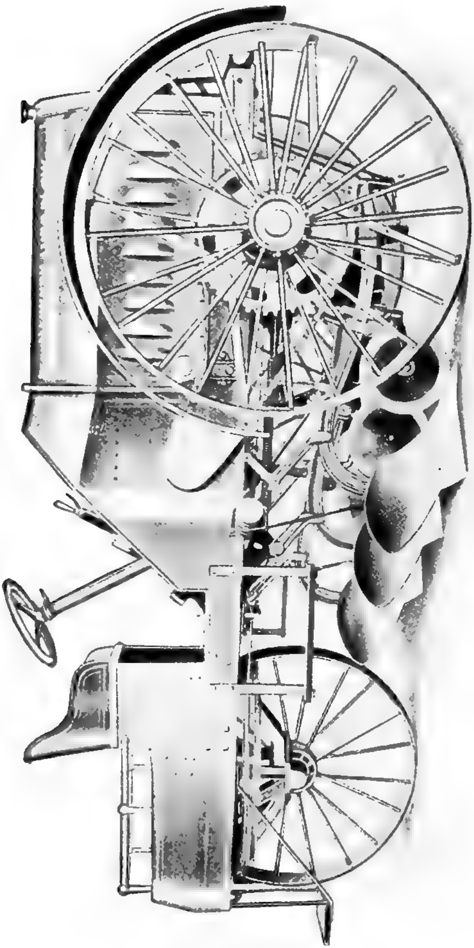


Fig. 86.—The Hackney Small Farm Plowing Tractor Carries the Plows as Part of the Machine.

wheels which apply their own power without the destroying footprint of the horse, should make our cultivated fields as smooth as a floor, and decrease the strain on the machinery we use by forty per cent. Instead of seed beds that in spots contain unbroken clods and poorly worked land, every foot of the land should be ground, and pulverized and crushed into almost a powder, until the dust-bed of the most intensive market gardener is obtained, thoroughly aerated, completely oxygenized, but still without the clodding effect of the horse's foot. Not only will the work of the harvesters be greatly reduced by the smooth, even ground over which they will travel, but the cultivation, in the case of corn, can consist more directly of soil culture without partaking of the nature of miniature plows and harrows, completing the work that in the seed bed was neglected. Experience has proven beyond question that a thoroughly tilled field is given a fair coating of manure every time its soil is brought into thorough contact with the oxygen of the air.

As a cultivator the ideal tractor will be readily stripped of its broad wheels and a narrower set provided which will enable it to traverse the rows with a set of crust breakers and soil aerators that will cover several rows at a time. The rows in planting are measured accurately and run absolutely straight. As a cultivator the same width setting should be used, then the minimum amount of guiding will be necessary for working one row or many at a time. With the same set of wheels, the field spraying should be done; and with such facilities it will be done, and will not be neglected.

369. Trailers Not Satisfactory.—For most of our eastern farms trailers will not answer, for they require

too much space in which to turn. Some of these late self-contained plows claim to turn in a space of from eight to fifteen feet, while the old heavy tractors required something like fifty, not including the train of implements which they dragged along behind.

FIG. 87.—The Broad Wheels of the Gas Tractor Should Make Cultivated Fields as Smooth as Floors and Add Greatly to Life of Machinery.

370. Cost of Tractor Farming.—This is determined so largely by individual conditions that anything more than a general estimate is out of the question. Perhaps of all farm operations plowing furnishes about the most uniform conditions and may be compared most accurately.

In a number of competitive tests with all kinds of

tractors the cost of plowing an acre has ranged from 18 cents up to $1.00, or perhaps a little more. The smaller figures however do not include the wages of the operator—just the fuel, lubricating, and other cash expense; while in the higher estimates are included the wages of men, interest on investment, depreciation and all legitimate expense. With all of these included, from 40 cents to 50 cents per acre seems at the present time to be a fair cost estimate, figuring the wages of the operator at $2.50 per day and board. Here is a fairly representative estimate with all the items included.

Cost of plowing for 10 hours.

1½ gal. gasoline	$0.20
57 gal. distillate	2.85
2 gal. lubricating oil	.40
Depreciation	1.20
Interest	.72
Labor, engineman	2.70
Labor, plowman	1.50
Board of men	1.14
Total	$10.71

Amount plowed 25.6 acres. Cost per acre $.418.

It will be noticed that this estimate is for an engine requiring the attendance of two men, while many rigs of equal capacity are now constructed so that only one man is needed.

CHAPTER XVI.

WHAT IS BEST IN THE TRACTOR.

371. **The Demand.**—Few more severe strains are ever put upon any form of machinery than that which falls to the lot of the farm tractor. Not only must it do a certain amount of work at the drawbar as its stationary brother does, and at the same time propel its own weight, but it must do this while traveling over uneven ground and constantly shifting positions in relation to its work. To stand this strain, all of the working parts must be made strong and heavy, and an important percentage of the power developed has to be diverted into the moving of its own weight.

372. **The Tractive Power.**—Weight is also necessary in order to increase tractive power, or the grip which the drive wheels get upon the ground. A light weight engine, even though it could be constructed strong enough and powerful enough, would fail as a tractor because a reasonable weight is necessary to insure firm contact and prevent the wheels from slipping upon the ground the moment a load was hitched to the drawbar.

373. **General Construction.**—The gasoline tractor consists of a gasoline engine mounted upon wheels, of which usually the two hind wheels are the drivers or tractors and the front truck a part of the steering gear. Usually the latter is equipped with two wheels like a wagon, but there are special forms of tractors now on the market where one broad wheel or roller

is substituted for the usual front wheels. Some tractors have the drivers in front, and at least one tractor recently brought out derives its tractive power from all of the four wheels.

Usually the power is transmitted from the engine to the drivers through a train of gearing of which a bull gear is cast or bolted securely to the drive wheel. This meshes with a pair of bull pinions, or one for each tractor wheel. A compensating gear or differential and an intermediate gear connect the bull pinion with a main pinion secured to the friction clutch and revolve with it on the main shaft with the fly wheel of the engine. This intermediate gearing is necessary for two reasons. First, it reduces the speed from the fly wheel rate of several hundred revolutions per minute to a safe rate for engine operation over rough ground; second, it permits the engine to be located in the most convenient place, even though not always in close proximity to the drive wheels.

374. **Other Forms of Transmission.**—While gear wheels are in almost universal use in steam tractors, and are most common in gasoline tractors, some other forms of transmission are occasionally seen. Friction gearing is becoming more and more a favorite, for one reason, because of the greater range it allows in the matter of speed. In some home-made tractors, too, belt power has been utilized, though it is hardly necessary to add that most of these have little power beyond that of self propulsion. Chain driven tractors, too, are in occasional use for light forms of work, but the gear wheel occupies a place with heavy tractors that nothing else has yet usurped.

375. **Steam and Gasoline Tractor Differences.**—In most respects the gasoline tractor is merely a steam tractor without the boiler, and its mounting is more

simple. There are, however, certain radical differences, of which one of the most important is the methods necessary for reversing and for changing speed. Steam engines can be made readily reversible, the forward or backward movement being accomplished at will through the engine itself. In the gasoline tractor this has to be accomplished in the transmission gear, different sets of cogs being thrown into mesh for high and low speed and reverse. All gasoline tractors are

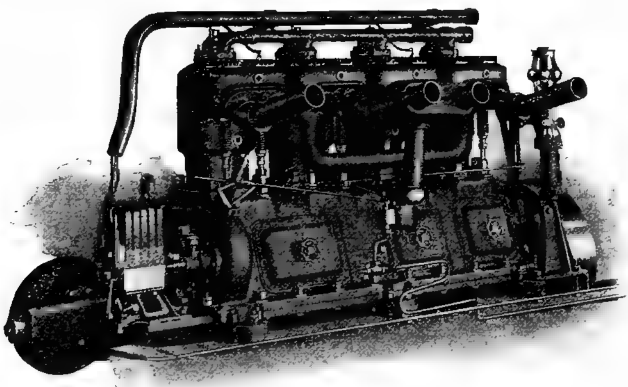


FIG. 88.—The Power Plant Is the Heart of the Tractor. Many Present Day Traction Engines Are of the Four Cylinder Four Cycle Type.

limited to two or at most three speeds ahead and reverse. The starting of the gasoline tractor has also been more of a problem than for the more elastic steam, though it is one that has been worked out at the factory rather than on the farm. A steam engine may be started very slowly and gradually speeded up. The gasoline engine speed is practically continuous almost from the first turn of the wheel; hence, far more depends upon the operator and the management of the clutch in the gasoline than in the steam tractor.

Friction gear tractors have, of course, a greater elasticity of speed, but they obtain it from the transmission and not from the engine.

376. **The Best Engine.**—Most of the best tractors now on the market favor the four-cylinder four-cycle type of engine with oiling system incorporated in the crank case. The water jacket should be ample, and, if the thermo-syphon system is used, the water spaces must be generous in size. The crank shaft and bear-

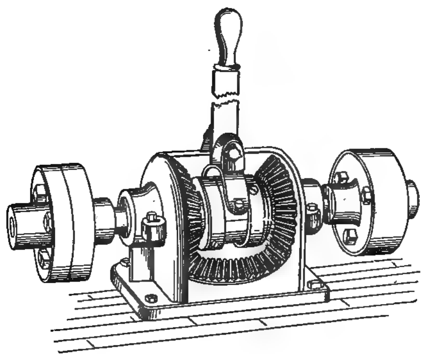


FIG. 89.—Bevel Reversing Gear Train.

ings must be heavy, and, of course, the lubricating system is of far greater importance than in the case of engines designed for lighter work. The exhaust pipe should be large and, if noise is not too much of an objection, the muffler should be dispensed with. This adds materially to the power and subtracts from the cost in fuel. The power of the engine should be carefully calculated to the work. There is always the possibility of too powerful an engine in a tractor just as there is in a boat. Power enough, with a reasonable reserve, is necessary. More than that means unnecessary torsional strain—and weakness.

377. **The Clutch.**—Since this regulates the application of the power to the work, the life of a tractor depends very largely upon the clutch and its operation. An irresistible power applied of a sudden to an immovable object means catastrophe, and that, to a limited degree, is what it means to turn the full power of a gasoline engine operating at top speed suddenly loose against the transmission of a tractor which is at rest. Either the gear wheels must be stripped of

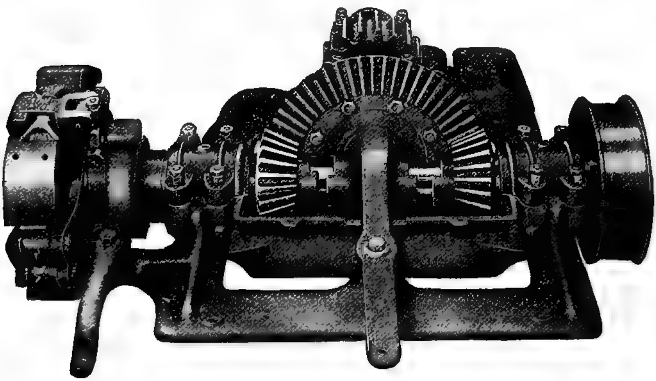


FIG. 90.—Reversing Gear of Gas Tractor.

their teeth or there will be a tremendous strain upon both engine and tractor connections. It takes a good deal of power to bring several tons of metal into action, and it is the mission of the clutch when properly handled to effect this work without undue suddenness. Most clutches and the pinions they carry to engage the transmission gear are not fixed upon the main shaft of the engine where they usually run and only revolve with it when the toggles force the clutch blocks out solidly against the inside of the belt-wheel's outer rim.

378. **The Transmission.**—There is room for a good

deal of difference of opinion with regard to the strength of transmission required, one operator getting along nicely for years with gearing that another would strip in a day. The farm engine, though, needs to have much heavier gearing than the thresher engine only. Good authority estimates that the relative strain placed upon the threshing and the plowing tractor is about as 30 to 70. While this estimate may

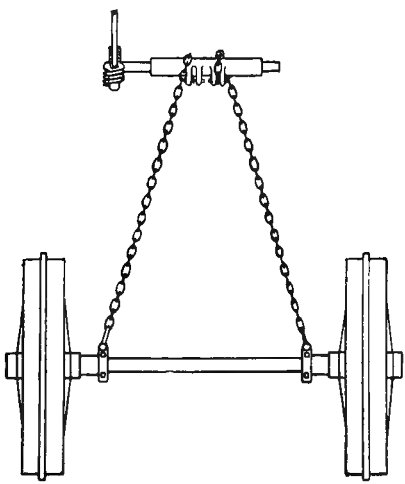


FIG. 91.—Typical Tractor Steering Gear, Front Truck Showing.

seem a little high, the main gear of a plow engine should not be less than a 6 or 7 inch face, while some thresher engines are only 4. This difference in required strength accounts at least in part for the number of thresher engines which have been ruined through being harnessed to the plow. They may have sufficient power, but they haven't the means of transmitting it.

Tractor wheels, too, should be broad enough to in-

sure good grip. Usually they are provided with spurs or lugs to prevent slipping, and there is quite a prevalent opinion that their power to hold is materially greater if the lugs are sharp and new. This is not always the case. Particularly on springy sod, the sharp edges of the new lugs cut away the ground more readily than the rounding corners do, and as long as the ground is merely cut and thrown back the tractor is powerless to move. Large wheels travel over soft ground best because there is a greater bearing surface and a small angle of contact at the front of the wheel.

379. **Differential or Compensating Gear.**—The use and construction of the compensating gear are so seldom understood that it seems wise to give the subject a little special notice.

If the two drive wheels of an engine were fastened rigidly upon a shaft and the entire shaft revolved, it is plain that both wheels, if of the same size, would not only turn over an equal number of times but they would both roll forward the same distance upon the ground. This is exactly what is wanted so long as the engine moves in a straight course over level ground. If, instead of revolving the shaft, we applied power to each wheel by means of revolving pinions of equal size, we would accomplish the same result. Both wheels would travel ahead the same distance and at the same speed.

If we now wished to turn a corner we would find it impossible, since in turning it is necessary for one wheel to advance faster than the other and describe a greater arc in the turning circle. We might provide for turning by applying the power to only one wheel, but that would reduce the tractive power of the engine one-half. Or some means might be devised of throwing the one wheel out of gear while turning by means

of a lever, but that would hardly be convenient, especially when we came to a field of which the surface was so uneven that in effect the engine would be obliged to make almost continuous little circles, first with one wheel and then with the other. Some means of relieving either wheel automatically on demand without releasing it from its work is necessary, and that is exactly what the differential does.

380. **How It Works.**—Let us suppose that three pulleys, numbered respectively 1, 2 and 3, are suspended close together on a shaft on which they revolve loosely and independent of each other. By so placing them that a spoke in 1 and 3 are in exact line and say two inches in advance of the spoke in 2, and then thrusting a two-inch rod or bar across between these spokes, it is evident that if we turn 2 the wheels will all revolve at the same speed. This will continue so long as 2 revolves and the bar remains at right angles to the pulleys.

Now if we should attempt to revolve No. 1 a little slower than 2 was turning by retarding it the bar would be swung around the spoke of No. 2 as a pivot, and if we continue to retard No. 1 the bar will finally be so far deflected from its first position that its ends will slip from the spokes of both 1 and 3 entirely. By thrusting a second bar through at this instant in the same position the first bar originally occupied the process would be repeated and would of course continue so long as we replaced each bar, as it slipped away from the spokes, with a new one, providing we still continued to retard the same pulley with the same force. If the spokes were properly spaced in relation to each other and we could slip bars in fast enough to keep one at right angles constantly as well as at all the angles between that and the point where it

slipped past the spokes, there would be no change in the influence of one wheel upon another, even though the one still continued to move at a slower rate.

Let us now substitute for the spokes and bars a pair of bevel gear wheels, the smaller one revolving on one spoke of pulley 2 for its axis, each tooth of the larger wheel taking the place of a spoke and each one on the smaller pinions answering for one end of the bar. As each tooth slips out another is slipped in to take its place mechanically, so that the action is continuous. This principle is introduced not only into the traction engine, but in other similar machinery one wheel of which must occasionally turn faster than the other. By this means one of the tractor wheels is free to travel much slower than the other, while both are still doing equal tractor work.

381. **Power of the Gasoline Tractor.**—In estimating the horse-power required in a gasoline tractor we must remember that the power of a horse is measured by his effective pull, which is made while he is in motion. No tractor can propel itself about and at the same time do the same work at the belt that it could do as a stationary engine. Some of its power is lost in transmission; much of it, in self-propulsion; hence it is unreasonable to expect a 25 H. P. engine to draw as much load mounted as a tractor as twenty-five horses would draw. The brake test rating measures power of a stationary engine only, and does not represent effective draw-bar pull.

Formerly some gasoline engines, rated the same as steam engines, when mounted as tractors gave disappointing results because a tractor when pulling its full load is being almost constantly overloaded for an instant by the little obstacles which even the smoothest ground presents. When one of these is struck the

steam engine's more elastic power will carry it over, and then it will recover while the load eases down. The gasoline tractor hasn't the reserve; it has to stop.

Gasoline tractors, too, when used for threshing purposes are being continually "tested," "crowded" and "tried out" by hostile or curious threshing crews,

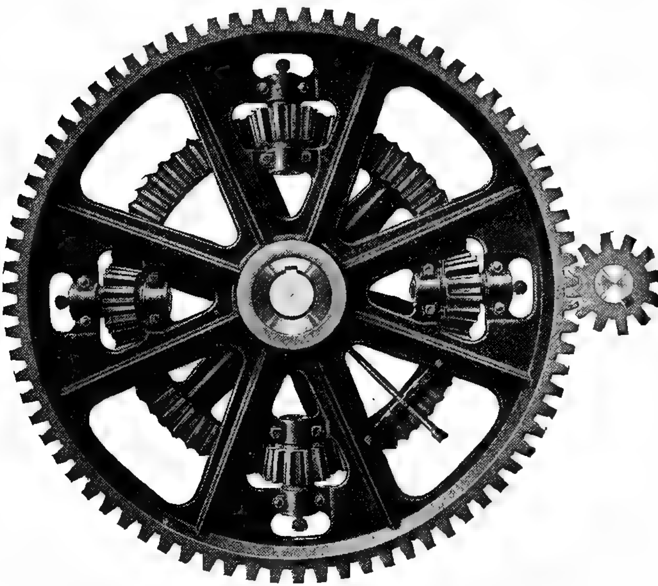


FIG. 92.—Bevel Differential and Spur Driving Gears of I. H. C. Tractor.

some of whom would like nothing better than to "stall the new-fangled engine down." For this and various reasons it is wise to be certain that the engine purchased is large enough for the work.

382. **Power Needed in Plowing.**—The plow test is the hardest necessary test the tractor ever has, and, with plowing requirements provided for, the operator has no occasion to be afraid under any reasonable con-

ditions. Tests have shown that a pull of from 500 to 900 pounds is required to draw a plow 4 inches deep through gumbo soil. On ordinary farm fields one large engine user reports that with a 35 H. P. engine he can easily handle fourteen 14-inch plows cutting 8 to 10 inches deep and running at a speed of three miles per hour. For moderate sized farms 20 to 25 H. P. tractors can easily operate from 4 to 6 plows, while even more has been accomplished. Tractors of 15 and even 12 H. P. have been reported as doing satisfactory work on moderate sized farms, while in a few instances home-made tractors of special design have been made to plow with even less power. It is doubtful, however, if less than a 12 horse tractor of the trailer type can be regarded as a practical plowing engine for even one or two plows under most conditions, while a 20 to 25 horse will undoubtedly give far better satisfaction and be found most economical.

Specially designed plowing engines with the plows a part of the engine are illustrated elsewhere, and it is possible that further development along these lines will bring out a gasoline plow of much lighter power, one that will be wholly available for small farm plowing. Until quite recently it was believed that something like a 7 H. P. engine was required for the construction of a self-moving tractor. Home-made affairs constructed out of binder wheels, mowing machine wheels and other remnants of the junk pile proved the fallacy of this belief, and many ingenious farmers have at small cost rigged as small as 2 and 3 H. P. engines up as available tractors. Now one engine house manufactures regularly working tractors of as little as 6 H. P., while self-moving engines of 1½ H. P. are now on the market.

383. Home-made Tractors.—Perhaps the reluctance of the manufacturers in taking up the problem of farm tractors has had as much to do as anything with the number of home-made tractors which have been constructed and put into practical use by farmers and their boys. Some of them have been made in the simplest manner and have cost very little that could not be supplied from the old machinery on the farm. More elaborate designs have also been attempted, in some instances disastrously expensive, the cost finally reaching more than the price of a regular market tractor and the results much less. Until the manufacturers awoke to some idea of the opportunity they were facing, these home experiments seemed about the only way the requirements of the farm could be served. Now that special study is being given the subject by practical machine men it is usually much cheaper in the end to purchase a tractor than to construct one. The home-made tractor is an entire practicability, however, and for those who are unable to afford a factory-made one, and who are willing to put up with less convenience in order to get something that will do the work, it is often worth while trying, and for such people several home-made tractors are illustrated in this volume. Most of them are belt transmission, a simpler and cheaper form and a far less durable one than gearing. Probably most of the performances reported represent work done when the tractor was first constructed. Some of them have, however, been made at a cost a little in excess of $10 money outlay and were undoubtedly well worth what they cost, even though of short life.

For the lighter sort of tractors, mowing machine wheels are favorites as drive wheels, but for heavier work binder wheels are essential. Some of these

have been made to do quite heavy work, and under favorable conditions have even been harnessed to the plow. Discarded steam tractor wheels have also been utilized and engines of 10, 20 and even as much as 40 horse-power tractors have been made at home which were capable of any sort of farm work at all likely to be put upon them, and including threshing, and pulling the rig from barn to barn over hilly roads, ensilage cutting, corn husking, plowing, moving buildings and tearing out hedge fence. While such ambitious efforts have been frequently successful, it is well to remember that the first attempt of an amateur in tractor-building is at best only an experiment, and it is well not to undertake it upon a scale that will sink too much time and money in the venture if it proves disappointing, until some experience is obtained by smaller ventures.

CHAPTER XVII.

OPERATING THE TRACTOR.

384. Preparing for the First Start.—The man who is at all self-conscious or easily confused by the com-

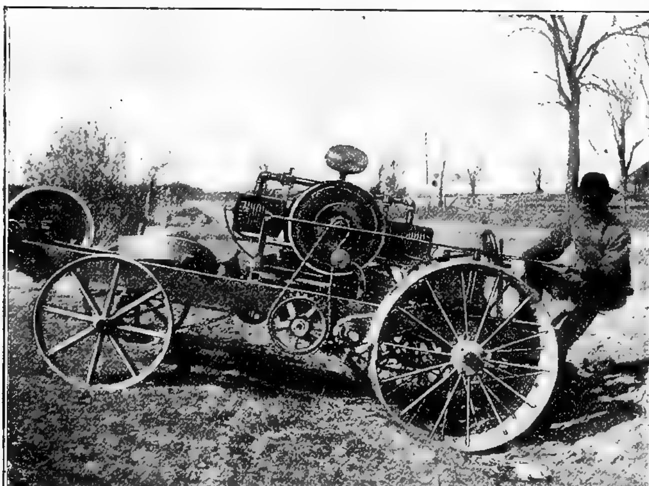


FIG. 93.—Simple Home Made Tractor and Circular Saw Stand.

ments of other people had better restrict his audience to one or two efficient helpers, and it might be well enough to give these helpers plenty of their own work to do. A good many men, in control of their first tractor, have landed it in the ditch at the start, perhaps at the same time trying to check it with a

strenuous "whoa." An experience of this kind is rather stimulating to a crowd of idle spectators; also, it is somewhat confusing to the man who has made the blunder. Any man needs all of his attention centered upon his work when starting his first tractor, without having any distraction by the comments of a crowd.

By all means if possible make the first start at some

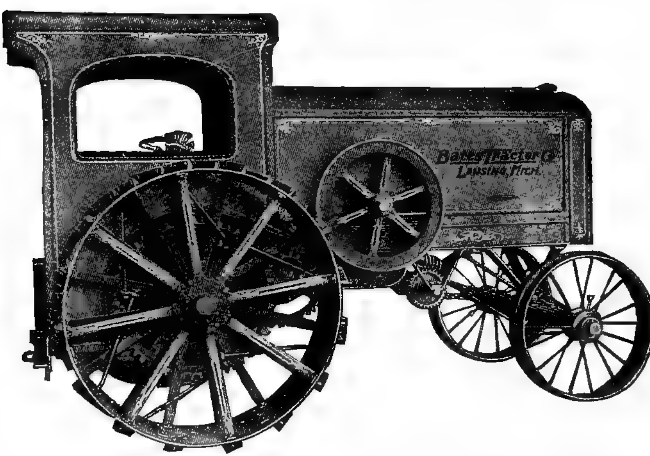


FIG. 94.—A Recent Factory Output With Enclosed Power Plant and Mechanism.

place where there is plenty of room. At any rate, avoid the street or any place where a short misdirected run may endanger the operator, or the engine, or the lives of other people. A level field with a firm, hard sod is the ideal place.

Before attempting to start, try the spark and see that the current is all right; also make sure that there is gasoline in the tank and that it is coming over properly. No steam engineer would think of starting

without looking to see if he had plenty of water, fire and steam. Oil the engine as though it were a stationary affair and, after making sure that the clutch is disengaged, set the fly wheel in motion. While it runs, go over the transmission and tractor part and see that everything is in order and with a good supply of lubrication. Remember that a more liberal amount is needed when first starting a new tractor than after the bearings have taken on their glaze. Notice while oiling that there are no cinders or bits of metal in the oil holes or at any place where they will be likely to get into a bearing. Look the position of the levers over and be certain to know the use of each. Try the steering wheel enough to make sure that it will turn freely and that the front wheels of the tractor are not half blocked by an obstruction that will deflect them from a straight course. The steering gear is much harder to operate when the tractor is at rest than when it is in motion.

Examine the bearings of the engine to see that nothing is heating and that it is working properly as an engine. You will have no time to consider the engine itself when first beginning to operate the tractor.

385. **Starting.**—If there is a moderately extended clear course straight ahead, as there should be, with the steering wheel bring the front truck of the tractor into place, at the same time noticing whether the steering chains are too loose or too tight. If the former, the tractor will be hard to guide because it will not respond quickly enough; if the latter, there will be excessive friction and strain.

Lock the steering gear in place for a straight course ahead (most tractors have provision for this), and so be rid of the details of guiding the engine at the in-

stant of starting. Engage the clutch carefully, not suddenly enough to set the transmission into action with a jerk, but without letting the rim of the fly wheel revolve unduly long against the clutch arms after beginning to make contact. It takes some little skill to do this always at the happy medium, but practice will bring the skill. The tractor should be first started on slow speed.

386. Learning to Guide the Tractor.—As soon as the tractor is fairly started unlock the steering wheel and hold it to a straight course with the hand. A skilled engineer can tell much from the "feel" or vibration thus conveyed to him. After becoming somewhat accustomed to this quivering sensation under normal conditions and well before there is any necessity for forced action, begin to experiment a little with the steering wheel by turning it slightly and then bringing the engine back to a straight course again. If the chains are properly adjusted the wheel need not be turned far in order to change the direction of travel quite a little. Continue this practice first in one direction and then in the other for some time, but do not attempt any short turns. Aim to acquire the habit of bringing the tractor about easily and smoothly rather than by means of abrupt and sudden changes.

Before reaching the end of the field, and with plenty of room ahead, begin to bring the engine around for the return trip, first in a wide circle, then narrowing down to a shorter turn after getting familiar with what a certain amount of changing the steering wheel will do. Remember always that neither the new engine nor the novice in operating should be given a severe test at the start. After a little practice at slow speed the higher speed may be undertaken,

and after that the reverse. The first run should not be a lengthy one without a stop and examination for hot boxes, nor should any attempt be made to run near deep ditches, bridges, or to turn in narrow places until considerable self-confidence seems justified by previous control. In stopping, the novice should always try to select a place in which there is reasonable space for starting again. To find out in advance just how short a turn may be made with any engine, cramp the wheels around, while it is stationary, as far as would be advisable when running, and draw a line directly under the front axle, extending it some distance from the engine. Next draw a line under the rear axle and continue it until it intersects the first line. This point of intersection will be the center of the circle within which the engine can turn, and to find the exact amount of room needed double the distance from this point to the further side of the truck.

Perhaps the most important rule of all in tractor guiding is to run slow enough always to keep the tractor under perfect control and have plenty of time to use the steering wheel. If the place is specially difficult or the turn unusually short this is particularly important. By always following this rule and watching the front axle of the engine closely as a guide, the problem of steering will soon become almost wholly automatic and need give one but little concern under ordinary circumstances.

387. **Mud-hole Philosophy.**—So long as there are mud-holes tractors will get into them occasionally, and it is probable that there will be mud-holes as long as tractors last. The first thing to do is to keep out of them; the next, not to get in deeper. It is a great mistake to turn on all the power available, and possibly the high speed into the bargain in a case of this

kind. The momentum a stuck engine will acquire is very little, and it is always safe to remember that the tractor which is moving slowly, so long as it is really moving, stands a much better chance of climbing out than if an attempt is made to hurry it. The tractor can pull ahead or back only so much as the ground into which it thrusts its wheel lugs holds for it to pull against, and the ground is far more likely to hold if the strain is thrown upon it very gradually, so that it has a chance to compress than if it is hewed and torn violently by rapidly revolving lugs. The moment the wheels begin to slip and spin around shut off the power, as a slipping drive wheel will dig a deep hole very rapidly.

Often the tractor will climb out of itself if it can only be given something that will not allow it to slip. Pieces of fence rail, straw, plank, anything in fact into which it can sink its lugs and not have them break out again, will help. If that fails, a long rope hitched to the main shaft and then carried ahead and hitched to a tree may be sufficient; then start the engine and wind up the rope on the shaft. If a chain is handy drop it into the mud hole ahead of the tractor wheels; then start the engine. So long as the wheels can be turned the engine is ready to pull itself out if something can be put under them that will hold and not permit them to slip. If the engine cannot turn its wheels, probably the only way out of it is to dig the tractor out.

388. Sandy Places.—Always aim to run the engine as straight and as steady as possible in crossing patches of sand, so as not to break the grip of the lugs loose by disturbing its surface. The weight of the engine helps to pack it down; on a straight, steady pull it may hold, but to screw and twist the wheels

across it is only to loosen up the surface without doing any good. Often a bale of hay or straw will save all trouble if scattered ahead.

389. **Bridges and Other Obstacles.**—The farm tractor is not often called upon to cross a bridge unless in use hauling a heavy load to market, but occasionally a bad bridge is encountered. A strange bridge should always be examined before attempting to cross and, if it shows much wear or rotten plank or timbers, should be avoided if possible. If it must be crossed, a couple of long planks three inches thick at the center and tapering to two at each end may be laid across to run the tractor wheels on and so distribute the load over more of the bridge at once. For a longer bridge use shorter planks at each end of the long ones. Always carry a supply of good plank along when traveling on the road with a tractor unless familiar with the condition of all of its bridges. A long rope should also be at hand so that the load drawn behind, if any, can be hitched back far enough to be clear of the bridge until the tractor has crossed it. Run very slow across bridges and avoid sudden jerks or anything that tends to set up vibration.

Hill climbing with a gasoline tractor, unlike that needed when using steam, requires no special precautions other than to climb slowly and without any attempts at gaining an advantage by the use of sudden spurts. No advantage will be gained, and every jerking strain should always be avoided.

Occasionally some seemingly good authority will recommend the surmounting of small obstacles which are too much for the engine at ordinary speed by throwing out the clutch until the engine is running at full speed and then throwing it in again suddenly. If one is willing to risk stripping the cogs from a gear

wheel and the certainty of a very severe strain upon every part of both the engine and the tractor, this plan may be adopted, but not otherwise. Under all conditions it is the aim of the really skillful engineer to handle his tractor as quietly as possible, to avoid all useless strains and sudden jerks, and to make every move count in the right direction. There is no bluster or swagger about the man who is fully master of his job.

390. **Speed Allowable.**—When running on good roads the gasoline tractor may be put upon the high speed without any serious risk, providing the operator has skill enough to guide it. As this is not over five or six miles an hour with most engines, a little practice ought to give him this. Obstacles, lack of skill in the engineer, and increased vibration are about the only things that make it necessary to keep the speed of the engine down when traveling over fair roads. In plowing again the speed is determined more by the plow than by the engine. Usually 2½ to 3 miles per hour is considered about right.

391. **Hauling with Tractor.**—Approximately the load a tractor of known power will draw with wagons as trailers may be figured from the fact that with 1½-inch tires a weight of one ton shows a resistance of 121 pounds on broken stone roads and of 466 pounds on freshly plowed land. With 6-inch tires the proportion is 98 to 323. A common earth road gives a resistance of 100 pounds per ton to the tractor power with an addition of 20 pounds extra for each per cent. of grade.

392. **The Real Tractor Danger.**—The man who can run any kind of a gasoline engine will generally find that any difficulty he may have with a tractor is a matter of his own fault. He may be careless and

attempt to run his engine without proper provisions for controlling it. With such a man a few tons of metal in motion may become a public menace; so, for that matter, would the same man render a spirited horse dangerous. He may be prone to take the advice of others and so fall a victim of every one who has a curiosity to see how some pet theory of his own would work out—at somebody else's expense. He may like to show off and may believe that starting things with a lively bang and bringing them up with a whirl looks fearless and skillful.

The really skillful engineer sees to it first of all that everything about his engine is in working order, and he tries to avoid all risks and strains which might incline to put it out of that condition. He shows his skill by keeping as far away from trouble as he can, by starting up quietly, without any jerks and strains, by doing everything with as little fuss and swagger as he may. If people offer him advice he receives it for what he thinks it is worth, studies it over in his own mind, as well as the source from which it came; then, if he thinks it good, perhaps makes cautious use of it at some future time—after he has given it due consideration.

393. **General Care of a Tractor.**—All that applies to the care of an engine might be repeated in connection with the tractor, and to this may be added such shelter and protection as any reasonable man would expect to give any sort of transmission machinery which operated between his investment and the profits he expected from it. Some tractors are weatherproof —for a time. The writer knows of none that are injured by reasonable protection when idle or that are improved by exposure to every passing storm.

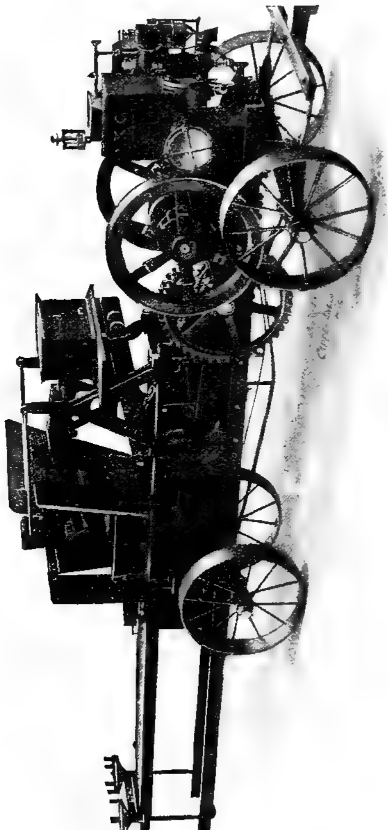


FIG. 95.—A Gasoline Engine Operated Hay Press.

CHAPTER XVIII.

POWER TRANSMISSION.

394. **An Important Problem.**—The best engine in the world is of no value on the farm or anywhere else if the power it develops cannot be transmitted to some other machine. Every one knows this, but not every one realizes what a difference there may be in the manner of transmission or how easily the power that is developed in the engine may be thrown away while conducting it to the work.

395. **Methods in Use.**—Shafts, belts, and gear wheels are the means most commonly used for transmitting power from its source to the place where it can be converted into work. Nearly all the rarer methods are merely modifications of some of these. For instance, the belt drive may be accomplished by a rope or by chain and sprocket wheels as well as by means of the usual form of belt and pulley; gear wheels may include friction as well as tooth gearing; shafts may refer to revolving rods or to various forms of levers.

396. **Shafting.**—Usually when we speak of shafting it refers to rods which revolve and carry pulleys or gear wheels somewhere along their length. They are usually of metal and the better the material the less the shaft will cost in power. Cheap shafting is one of the most serious means of wasting power in the transmission.

397. **Why Poor Shafting Does Not Pay.**—Shaft-

ing should transmit to the pulleys or wheels that it carries whatever working energy it receives, less that amount consumed by friction at its own bearings. Where a steel shaft of the best quality requires 1 H. P. of an engine to revolve it a given number of times per minute a cheap iron shaft of equal strength would weigh nine times as much and require something like a 28 H. P. engine to operate it at the same rate. As the power consumed by friction is a con-

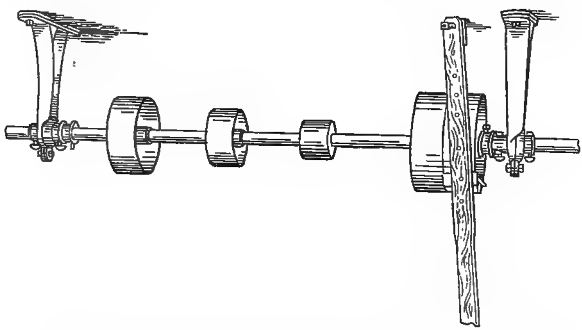


FIG. 96.—Countershaft and Hangers Ready for Belts.

stant expense while running, it will be seen that cheap shafting is the most expensive in the world.

Shafting should be of the very best material in order to reduce friction by reducing the size. It should be absolutely straight because it requires a good deal of power to spring even a two-inch line-shaft into line once during each of its 200 or 300 revolutions per minute. All of this power comes out of the engine, but the strain is divided between the engine, the shaft bearings, and the belt. A shaft should be somewhat elastic or it will quickly crystallize and break. If possible the driven pulley should be toward its center and between two bearings. By

all means, if it can be done, avoid applying the power on one end and taking work off at the other. When this must be done on a long line the shaft should be composed of lengths decreasing in diameter, and the power should be applied at the heavy end. A lighter shaft can be used if the strain is applied between bearings instead of at the end, and friction thus avoided.

398. **General Shaft Wisdom.**—If possible, heavy shafts should have their bearings rest upon posts with a ground connection, as there is always more or less spring in any ordinary floor. Avoid shifting weights on the floor above long shafting that is hung from the ceiling as the floor is constantly springing them out of line.

Line shafting hangers should not be over 8 feet apart, and if the shaft is light they must be closer. Even the smallest engine needs not less than a 1 3/16 shaft. Approximately, the horse-power a good shaft ought to stand may be found by multiplying the cube of its diameter by the number of revolutions per minute and dividing the result by 82 for steel and 110 for iron. The amount of power that can be transmitted by two shafts of similar quality varies directly with the speed of revolution and with the cubes of their diameters.

The twisting strain upon a shaft is greatest near the main drive and, aside from friction, is zero at the bearings; hence, the nearer the main drive is to the bearings the more nearly will this strain be counteracted.

A disregard of any of these principles not only wastes power but delivers an unsteady, jerky energy to the machine driven, and affects both its life and efficiency. In many instances the shifting of the main drive from the end of a shaft to a point between two

bearings has been known to overcome trouble that had previously prevented the operation of a machine.

399. **Balancing Pulleys.**—If the shaft is a long or a light one the question of balancing weights and strains along its length may become specially important. The heavier driven machines should take their power from the shaft at points not far from where it is applied, and two heavy machines should be set on opposite sides of the drive pulley. This is true to some extent whether both machines are to be run at the same time or not, since the pulleys driving them will be heavy and this arrangement will better distribute the weight. A heavy belt pull or even a great pulley weight at the end or anywhere along the line that is not properly supported by the bearings may throw the whole shaft out of line.

400. **Speed of Shafts.**—The relative speed of the driven and the driving pulleys of course determines that of the shaft, as one of the uses of the latter is to temper the speed to the machine. Where only one machine is driven from the shaft the problem is easy, providing the speed of the engine and that required by the machine are known. (See rule elsewhere.) If several machines of different speed are to be run by the same shaft it is sometimes necessary to take an average between the highest and lowest speed required and then make up the additional difference by varying the size of the pulleys. This avoids extremely small or extremely large pulleys.

401. **Size of Pulleys.**—To determine the size of pulley needed on shaft when there are given the speed and diameter of the engine pulley and speed of shaft, multiply engine pulley speed by its diameter and divide by the speed of the shaft.

402. **Pulleys.**—Pulleys are made of cast iron, steel,

wood and paper; and, of the four, iron is in more common use than all of the others united. It is more compact and neater than wood, and cheaper than steel, although a wooden pulley can be safely speeded up considerably higher than can an iron one of similar size and design. Wooden pulleys have the advantage, too, of holding the belt better. They are

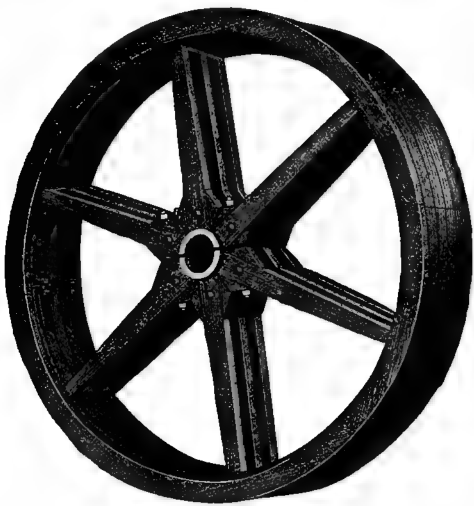


FIG. 97.—Construction of Split Wood Pulley.

usually made, in the larger sizes, in the split form; that is, they can be divided into halves, secured upon a shaft without disturbing other wheels, and then bolted together. Iron pulleys may also be obtained in the same form and, if large, are safer than when cast solid, on account of possible defects in the latter through the contraction of the iron.

403. **Straight and Crown Face.**—Iron pulleys are usually made crowning, that is, slightly oval, across the

face, where there is no belt-shifting to do, as a belt will always hunt the high place in the pulley, if there is one, to run on, and by giving it a high place in the center of the pulley it can easily be kept there. Some machinists object to the crowning face because it throws the entire load upon the center of the belt instead of distributing it, but nearly always where a

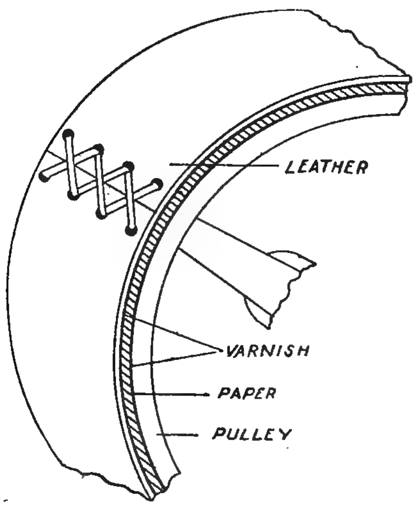


FIG. 98.—Method of Covering or Lagging Pulley.

pulley is ordered one with a crowning face will be sent unless the straight is specified. Where belt-shifting is necessary the pulley must be straight-faced.

404. **Use of Pulleys.**—Pulleys are used to convey power, to change speed, and to alter direction or form of motion. They are usually used in connection with a belt, but also in friction transmission and occasionally with crank-pins and connecting rods. More than 90 per cent. of power transmission, it is estimated,

is effected in America by means of the pulley and belt.

405. **Covering Iron Pulleys.**—Frequently an iron pulley does not hold the belt well and a great deal of power is lost in slippage. To overcome this pulleys are often faced with leather. One way of doing this is to clean the pulley thoroughly, coat with coach varnish, then a layer of soft paper and a second coat of varnish. Put on the leather, cut to proper size and length, and thoroughly clean; then lace loosely, as in Fig. 98; slip into place, and tighten lacing.

Another way, roughen face of pulley with cape chisel. Lace the proper length and width of cotton belting loosely and soak well in pail of paste made of cold water and flour. Slip this upon pulley and draw lacing tightly as possible. Put on more layers prepared in the same way, taking care to break joints each time. Then drive in Buffalo belt fasteners here and there to clinch against pulley. As the covering dries it will shrink and hug the pulley nicely.

In both cases, particularly the latter, it must not be forgotten that the diameter of the pulley has been materially increased and the speed must be regulated accordingly.

At least 25% may sometimes be added to the power transmitted by covering an iron pulley, as iron has a tendency to polish quickly and refuse to hold the belt. Cement and glue will not hold a leather covering on iron.

406. **How Secured on Shaft.**—Pulleys are secured to the shaft either by key seat or set screw. If the former, the key should be the exact width of the keyway and the latter, cut in both the shaft and the pulley, must match accurately; otherwise the key cannot be driven tight, the pulley will be forced away from the center and will soon work loose. If secured

by a set screw the latter should be kept tight enough to avoid slipping as, after a set screw has been allowed to slip a few times and thread the shaft, it will never hold as well.

407. **The Dangerous Set Screw.**—Perhaps no simple thing about machinery is more dangerous than a projecting set-screw head or similar projection on a revolving shaft. When in rapid motion it cannot be seen, and some one, while oiling a bearing, is almost certain to have the clothing caught and be drawn upon the shaft or at least have a finger or a hand destroyed by it. Always, if it can possibly be done, have every set screw deeply recessed and use a socket wrench. Test them frequently until they become thoroughly fixed, as the expansion of heat often loosens them; then, once they are thoroughly settled in their place, avoid disturbing them if possible.

408. **Other Pulley Dangers.**—Pulleys out of balance on the shaft run with a wobble that is ruinous to belts and machinery, and destructive of power. This may occur if the pulley does not fit the shaft or if the key does not fit the keyway; or the pulley may have been improperly cast or bored. A wabbling pulley should be fixed or else replaced; it costs too much to retain it.

Pulleys having a thick or thin edge at one side while true at the other may seem to stand up well when at rest, but run decidedly wrong when set in motion.

Small, high speed pulleys full of dust are dangerous; so are pulleys used as convenient shelves while removing nuts from some near-by machine. Never permit anything to be laid on any part of a pulley. If left there it may be hurled against someone with almost the force of a bullet when the pulley starts.

409. Tight and Loose Pulleys.—The tight and loose pulley consists of two pulleys, side by side, one of which revolves with the shaft and the other revolves upon it. By shifting a belt from one to the other the shaft and its machinery may be started and stopped at pleasure without disturbing the operation of the engine or of any other machine belted to the same shaft. It is a necessity in cases where one machine of several, belted to a line shaft, is frequently to be thrown in and out of motion.

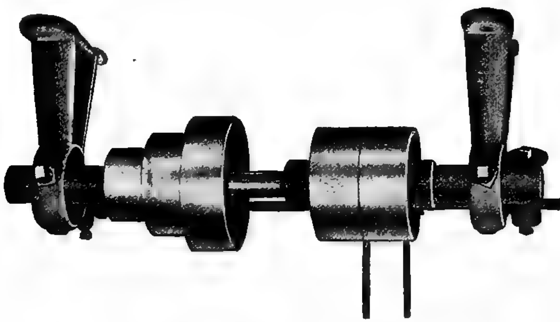


FIG. 99.—Countershaft Assembly With Tight, Loose and Stepped Pulleys.

410. Its Love for Trouble.—The loose pulley is generally thought a necessary nuisance, but much of the trouble comes from carelessness and neglect. The hubs should have an oil reservoir of some sort with a tight cover, as fully half of the oil used on most loose pulleys is wasted. Then the pulley should be started in right when new. First, it should be removed from the shaft and cleaned out thoroughly; then oiled; then returned to shaft and revolved on shaft under belt for a half hour. Remove, wipe off black coating of oil, dirt and iron particles; then, after it is clean, oil and replace, and run again. Repeat this until pulley

is absolutely clean; then it will take on a smooth polish or glaze. If properly oiled it will then run smooth and true for years; otherwise it will wear off at the edges in the shape of an hour glass, and speedily develop a wobble that will render all the other machinery silent by comparison. A good many of the loose pulley's troubles are due to the fact that it is not considered of enough importance to merit attention until it has developed the ability to out-clatter everything else in the place.

411. **Cone Pulleys; Their Use.**—Cone or stepped pulleys are sometimes used on farm machinery for the purpose of changing the speed of a shaft by shifting a belt from one section to another, but are in more common use on lathes and similar machinery of the shop. Usually connection is made between the two pulleys by means of a belt, though friction pulleys are frequently used in this way. The same principle is made use of with spur gear wheels in changing the speed of traction engines and automobiles.

412. **Home Made Pulleys.**—Sometimes one is tempted to utilize a rainy day and a few pieces of plank in making a wooden pulley, and so save the outlay of several dollars. Occasionally this is entirely successful, but it should not be undertaken unless one has facilities for turning off the face of the pulley absolutely true and for centering it accurately when boring it out. A good many home made pulleys are now in daily use and their owners point them out with pride as doing their work all right at only a fraction of the cost of a "boughten" pulley. The fact is, they cost less to obtain in the first place, but they are most of them wasting their price many times every season in strained shafting, strained belts, worn bearings and lost power. Not one person in a hundred

can construct and bore out a wooden pulley that will be absolutely true in face, bore and balance, unless he has better facilities for that kind of work than are available on the average farm.

413. **Bearings.**—The ideal bearing is a perfectly round hole surrounding an absolutely round shaft, and with just enough room between the two for a film of the proper lubricant. If this could be secured in the first place it is evident that it could not be retained because the pull upon any machinery doing work is in some one direction more than another, and the hole could not long remain round. Bearings for light, high speed machinery are generally made of phosphor-bronze or some such high-test, unwearable metal, but for heavier and slower running machines, babbitt is usually preferred, as it does not cut the journals and it is easily replaced when worn. Bearings of the same material as the shaft are not found suitable. They develop more friction and are more likely to abrade than are two metals of different hardness.

414. **Roller Bearings.**—Roller bearings have been proved by experiment to require less than half the power to overcome their friction that is required for ordinary babbitt bearings. While their use is being extended somewhat it is still of only limited application because they are rather costly and difficult to keep in order, on account of their reluctance to remain parallel. In theory their contact with the shaft is a line, but in practice it is a narrow parallelogram, a much larger surface than that presented in ball bearings. They have the advantage of a much longer bearing and can therefore carry a heavier load and carry it steadier.

415. **Ball Bearings.**—Ball bearings consist of a

number of hardened steel balls confined in grooved raceways (Fig. 102) and presenting but a small part of their surface to the journal. As formerly employed they were quite small, and sometimes gave trouble by jamming so as not to revolve freely, then the sides soon wore flat. Improved methods now in use produce them very accurately formed, and they are sometimes made as large as 4 inches in diameter and capable of sustaining a load of 50 tons. Theoretically, their bearing surface is a point only, but in practice it is a small circle. They are calipered and accurately sorted as to size so that all fit accurately into the same groove. Those to be used for shafting are fitted with an adapter to permit easy assembling.

When cheap bearings are used one of a set of balls may break and the sharp edges are likely to do serious mischief to the rest of the set. Of late their use has been greatly extended, because of improvements in design, and they are in quite common use in various machines which the gasoline engine is now operating on the farm, as well as in line shafting applications.

416. What Babbitt Metal Is.—Babbitt metal, named after its inventor, the late Isaac Babbitt, is somewhat variable in composition but is made up principally of block tin and antimony. In the better grades a little copper is added, while that of an inferior quality contains a little zinc. This causes the boxes to heat more or less, and is not so durable as the true babbitt. About 5 parts tin to 5 of antimony and 1 of copper is the usual proportion. The result is a soft white metal that is easily fused, and that has the peculiar property of generating little friction.

417. Preparing Boxes for Babbitting.—All the old babbitt, dirt and grease must be removed and the box washed out with gasoline. The box must be thor-

oughly dry or steam will form and cause trouble. Bolt the box into position so there will be no danger of throwing it out of alignment after the babbitting

FIG. 100.—Solid Box Bearing or Pillow Block.

is done. If the box is solid, that is, not cast in two pieces bolted together, wrap a paper smoothly around the shaft and gum the lapped edges fast. Otherwise,

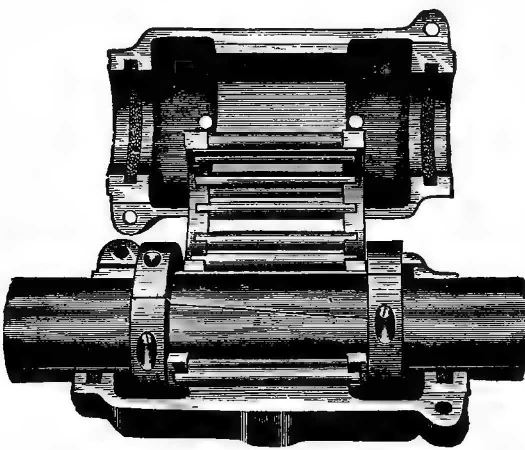


FIG. 101.—Sells Roller Bearing Shaft Box Fits Standard Hangers.

the cooling metal will shrink so tightly about the shaft as to hold it fast and make it necessary to break the box or subject shaft and all to the babbitt furnace. The ends of the paper should project a little beyond

the box. Block up the shaft so that it is properly aligned and central in the box, then close up the ends with stiff putty or clay. Vent holes must be left at the top for the escape of air and for pouring the hot metal into the box. The oil hole is sometimes used for this purpose; if not, insert a wooden plug through

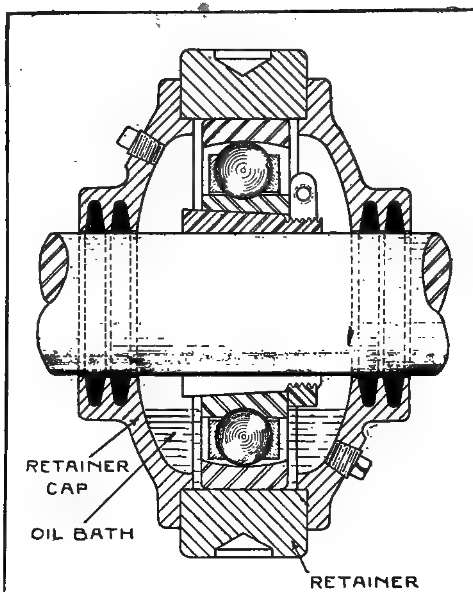


FIG. 102.—Sectional View of New Departure Ball Bearing Shaft Hanger Box.

the oil hole in the casting with the end resting on the shaft, and so save the bother of drilling it out afterwards. A wall of putty or clay should be made around each vent-hole to keep it clear of flowing metal.

418. Preparing the Babbitt.—A plumber's furnace is convenient for melting babbitt, as it is portable and

the metal needs to be poured hot. Some boxes require three or four pounds of metal, and the ladle must be large enough to hold the full amount for one pouring as it will not unite with fresh metal when once set. Heat the babbitt until it will brown or char wood. Test the temperature by inserting a pine stick occasionally.

419. **Casting the Bearing.**—When the metal is hot enough pour it as fast as it will run through the hole and without any breaks until it begins to come up through the air holes. Do not stop if some is spilled. It can easily be gathered up when cold. Keep the hot metal running in a full stream into the box and give attention to nothing else.

After it is filled and cool remove from the shaft, clean off the clay or putty, ream out the oil hole with the sharp end of a file, trim off the edges and, starting at the oil hole, cut a groove slanting down and across each side. These are for the oil to lie in against the shaft, and must not be forgotten.

420. **Babbitting a Split Box.**—The box is prepared in the same way excepting that pieces of cardboard or sheet-iron must be placed between the top and bottom half of the casting. These should be wide enough to rest tightly against the shaft and holes should be cut through them corresponding with the bolt holes through which the two parts of the box are bolted together. Enough of these shims or liners should be used to allow for taking up the box after the bearings have become somewhat worn. Notches should be cut in the ends of these liners next the shaft to allow the metal to run down into the lower half of the box. Rapid pouring is even more essential in babbitting a two part box than in a solid one.

When the metal is cold loosen the bolts a little and

with a sharp cold chisel break the two halves apart; then remove the top half and with a file trim off the edges, cut off the pouring gates with the cold chisel, file smoothly and with a round nosed cold chisel cut the oil grooves. The job is now complete and, after removing the paper from the shaft and smoothing any roughness noticed about it with emery cloth, the box and shaft should be thoroughly oiled and returned to place.

In bolting a split box together use the shims to build up the shoulders enough, so that the strain of the bolts when drawn down will come upon the shoulders and not upon the shaft. This is of vital importance; otherwise, the shaft will either heat or refuse to turn at all. It is also important to put the same thickness of shims at both sides, so that the stress on the bearing be alike all around. As the babbitt wears the shims may be reduced either by removing part or by using thinner ones, but they should always be reduced on both sides of the shaft alike. The bearings should hold the shaft firmly, but must not bind it.

Instead of casting the top of the box solid some prefer to fasten a strip of leather in the top around the oil hole before pouring and then fill this with wool as an oil holder, from any part of which the spiral oil grooves may be cut.

Do not attempt to use too small a melting pot, as it is practically impossible to use up all of the metal melted without some of it becoming too cold to run well. More than is needed for the job should be melted, the amount depending a little upon how convenient the furnace may be placed in relation to the job. On the other hand, too large a melting pot is heavy and inconvenient to handle. For the ordinary

run of farm work one holding five pounds would probably be about right.

Do not attempt to make a catch-up and hurry-up job of babbitting. The bearings are of enough importance to merit careful work and a good job, once done, need not be repeated for a long time, if the oiling is attended to.

CHAPTER XIX.

BELTS AND BELTING.

421. **Reasons for Using Belts.**—While the transmission of power by means of belts has long been known to the mechanical world, its wide application is due to America, European machinists until recently having favored gear wheels. In this country more than 90% of all power used is transmitted by means of belts in some form.

Belts are almost noiseless. Power may be transmitted by them at much greater distance than by direct gears. There is less risk from accidents. They are simpler and more convenient, applicable to a greater variety of conditions and, in case of a breakdown or a change in the position of machines, they may be repaired or refitted without sending to some distant factory for a machinist. For this last reason they are particularly valuable on the farm.

422. **A Few Drawbacks.**—In one respect belts are expensive; they are wasteful of power. The movement of gear wheels, properly set up, is absolute. One revolution of a 12-inch wheel will drive its mate a distance equal to its own circumference each revolution. Belts will slip; and while the per cent. of waste from slippage ought not to exceed 2% there is no question but that there is a much greater loss than this under average working conditions and that if the belts are not closely watched the loss is liable to be quite serious.

423. **Belt Essentials.**—The value of any belt depends upon four special qualities; strength, durability, absence of stretch and pulley grip. In special cases other things must be considered; resistance to moisture, flexibility, etc. The first four qualities are necessary, however, in any belt, and material which has not a fair amount of all of these is not suitable for belting.

424. **Leather Belts.**—Oak-tanned leather is the best of all for belts—it being strongest, most durable and best in nearly every way. It has the disadvantage of coming in short lengths, but these are so perfectly united in the modern methods of belt-making that the joints can hardly be found and in most cases do little harm.

425. **Rubber Belting.**—Rubber belts are made of several plies of cotton duck alternating with rubber composition, and then vulcanized. Their strength depends upon that of the fabric out of which they are built up, and is something of an uncertain quantity. They have the advantage when new of being waterproof, and may be made in any length with but one joint or even without any, endless belts being supplied to order by any belting house. Oil of almost any kind is ruinous to them and must not be allowed to come in contact with them. Rubber belts are specially valuable in the presence of steam and they stand a greater amount of both heat and cold than leather. They are less liable to slip on the pulley. In strength a four-ply rubber belt is counted about the same as a single thickness leather belt of the same width. The first cost of a rubber belt is considerably less than for a leather belt of equal capacity.

426. **Canvas Belting.**—Canvas belting is about the same strength as rubber and is lighter. It is much

used in connection with thresher engines but is less suitable between two fixed pulleys because it stretches and contracts with the weather.

427. **Care of Belts.**—The efficiency of a belt depends fully as much upon its care as on its original quality. They should be kept pliable and reasonably clean. A belt run too tight or under an overload will give out first besides causing trouble with hot boxes, broken pulleys and sprung shafting. It has been found by experiment that as high as 30% more power and considerably greater wear can be obtained from a leather belt by running it with the grain or hair side toward the pulley. If this is not done the less pliable grain side is likely to crack from being strained over the pulleys and, as this is the strongest side, the belt is seriously weakened. A cemented or lapped leather belt should be turned so that the pulley runs off and not on the point of the lap. All belts should be somewhat narrower than the pulley upon which they run as few things strain a belt worse than projecting over the edge at one side or the other and so being pulled across the rim.

Some belts do not stretch alike at both edges. If one inclines to climb continually toward one side of the pulley, reverse it. If it still runs on the same side the fault is in the pulley, the shafting or the alignment; if toward the opposite side it is in the belt.

Belts should be kept as free as possible from moisture and extremes of heat and cold. Under no circumstances oil a rubber belt. Put the oil on the bearing. The practice of throwing oil and powdered rosin on any belt, particularly rubber, to make it stick to the pulley is almost certain to shorten the life of the belt by months if not years.

428. **Belt Dressings.**—Avoid belt dressings as

much as possible. As a rule the belt that requires the use of a sticky dressing to make it adhere to the pulley is suffering from some form of abuse, such as overload or faulty drive. Many of the dressings on the market are decidedly injurious. Seldom if ever are any of them needed except for one of two things; to keep the leather in soft, pliable condition or else to tide over some emergency strain that, if avoidable, should never be placed upon the belt. A hard, glazed surface on a belt is a pretty sure indication of some form of injurious dressing, though it is not always anything that has been put upon the belt intentionally. It may be the result of some dust and moisture combination in the air, and occasionally it means overwork. In either event it ought not to be there. It will always be found more difficult to keep belts clean than to keep them soft and it is fully as important; in fact, if they are kept clean and not abused in any other way they are more than likely to be soft. If it is found necessary after cleaning it to soften a leather belt, use something with a neat's-foot oil foundation, but not mineral oils. If a dressing is found necessary to hold a rubber belt to its place—don't use it; instead, correct the load or the alignment. A belt should be wide enough to transmit twice the horsepower required of it.

429. **Size of Belt Required.**—The breaking strain of the best leather belting is given at 3,360 pounds per square inch of cross section and, figuring out the necessary factor of safety, the safe working strength is counted but one-tenth of that or 33 pounds per square inch or about 41 pounds per inch in width of belting 1/8 inch thick. This allowable strain in practice is still further reduced to from 30 to 35 pounds by the best authorities, presumably to allow for the ordi-

nary range of strength to be expected even in a good quality of belting. Some adhere, however, to the higher estimate. A belt one inch wide traveling 800 feet per minute is figured to transmit 1 H. P. and each additional inch should add 1 H. P. if conditions are favorable. The pulling power of a belt depends

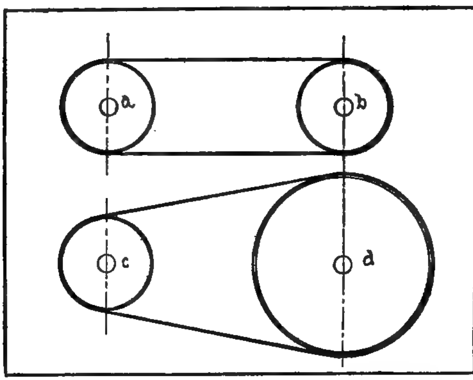


FIG. 103.—A Study In Belt Contacts. Two Equal Pulleys. a and b Have a Belt Grip of 180 Degrees. When Two Unequal Pulleys Are Used the Largest One, d, Gains in Transmission Efficiency, Because Belt Contact Is More Than Half the Circumference; the Smaller One, c, Looses Because Belt Contact Is Less Than 180 Degrees.

upon its frictional surface presented to the pulley and its pulling strength. A double leather, six-ply rubber, or six-ply cotton belt will safely transmit from 50 to 75 per cent. power, the usual rule being one horse-power for each one inch width at a speed of 550 feet per minute.

430. **A Convenient Rule.**—To avoid calculating the number of feet per minute that a belt is traveling a convenient rule is to multiply the diameter of the pulley in inches by its number of revolutions per minute and this by the width of the belt in inches. Di-

vide this product by 3,300 for single belting and by 2,100 for double. The quotient will be the required horse-power.

431. **Length of Belts.**—Within reasonable limits a long belt will transmit more power than a short one, and can be run much looser. To find the length of belt required between two given pulleys add the diameters of the two pulleys and divide by 2; then multiply by 3¼ and add the product to twice the distance between the center of the shafts. Where space

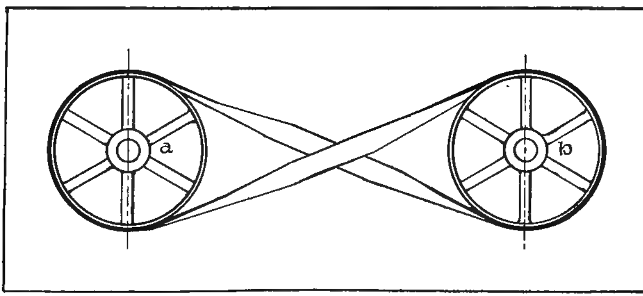


FIG. 104.—The Crossed Belt. Each Pulley Has an Arc of Belt Contact More Than 180 Degrees. In General, Loss Because of Friction in Twisted Belt Overcomes Advantage of Greater Belt Contact. Arrangement Shown Useful for Reverse Drive.

permits, a distance of 20 to 25 feet between pulley centers is a good working distance.

432. **Speed of Belts.**—Increasing the speed of a belt increases its power up to certain limits, but this cannot be carried beyond 6,000 feet per minute, as the power then begins to fall. In practice it is a safe rule in anything to avoid extremes, 4,000 to 4,500 feet per minute being a more economical and a far safer speed, while as little as 600 can be used. In lagging or covering pulleys it must always be borne in mind that

adding to the size of the pulley increases the speed of the belt.

433. **Belt Slipping.**—All belts slip more or less, and within certain limits it is an advantage, as the sudden obstruction of a load, such as the clogging of a thresher cylinder or similar accident, may merely cause the belt to slip when a positive drive like cog gears would cause a serious breakage. When a belt because of slippage fails to deliver 97 or 98 per cent.

FIG. 105.—Driving With Long, Heavy Belt, Showing Sag.

of the power it should transmit, the loss is too great. Most slips originate where the laced joint strikes the smaller pulley, which is where the contact is the least and is therefore most easily broken. It is important that the joint be made as even as possible to decrease the jerk at this point. Pulleys of about equal size hold the belt much better than where the difference of diameter is great, as the belt is in contact more nearly its full 180 degrees (see cuts). For this reason a belt that is long and heavy enough to permit considerable

sag without loss of necessary tension hugs the pulley better than a tight belt. On account of the greater tension, however, the tight belt will deliver the most power, but an over-tight belt consumes more power by increased friction on the journals and is less effective than one of moderate tension. Slipping creates hot belts and a tight belt causes hot boxes. By making the lower side of a horizontal belt do the power transmitting and letting the upper do the sagging the amount of contact is increased and the tendency to slip diminished. For small high speed wheels, light, soft belting hugs the pulley better than heavy or double belts.

Nearly three times as much power can sometimes be transmitted from a leather faced as from a smooth iron faced pulley. Manila paper answers a similar purpose, and if smoothly put on and not overloaded will last for years. Soak good glue in its weight of wafer till water is absorbed, then melt. Roughen pulley face with acid or coarse file and spread on glue, then paper, rubbing on with a brush to expel all air. Use several layers of glue and paper; or old split belting or split leather may be used if desired.

When a belt once slips badly it is more difficult to hold, and it is more important to guard against the first slip than to correct it afterwards. Wet belts are sure to slip on iron and are injurious to wood pulleys, hence should be dried before used. Belt dressing that contains mineral oil or rosin soon coats belt with a glaze that is fatal to holding unless kept constantly sticky; then it is disagreeable to handle and catches all the floating dust and dirt. A belt once glazed by dope is half spoiled, as the natural oils of the leather are drawn out and the fiber deadened. If a belt becomes hardened castor oil may be used to

restore it partially. One of the worst dangers of belt dressings is the fact that any of them work well at the start.

434. **Belt Hints.**—Cold weather is hard on belts. When first starting, run without load until they are warmed up.

Tight belts are expensive in leather, power and bearings. A belt so tight as to cause the loss of power by friction at the journals to exceed 20% of the load may be classed as a tight belt.

Six-inch belts or heavier should have bearings on each side of pulleys.

Old belts that are saturated with grease are hard to hold. They may be partially restored by sprinkling Fuller's earth or prepared chalk over them to absorb the grease and then scraping with a wooden strip slightly sharpened.

Narrow double belts are more economical, efficiency considered, than single wide ones.

A rubber belt from which part of the rubber surface has been worn will shrink badly if wet.

Cheap grade leather belts are fair for light work and slow speeds, but are not suitable for heavy or high speed machines.

Belts running curled over the edges of pulleys may be due to faulty alignment in shafts, a slight taper in the pulley, a hanger support that yields under a pull, or to the uneven stretching of the belt.

Belts should be run with a slight wavy motion on slack side, showing slight tension. Swaying is caused by pulleys being out of line or out of balance, or there may be an unevenness in the thickness or the pull of the leather. At rest the edges of the belt should hug the pulley.

To avoid as much friction as possible, belts should

be run at rather high speed and with less tension. Heavy pulls should come near hangers and ought, if taken from a line shaft, to be delivered to the side opposite that from which the power is taken in order to have the pull of the machine in some measure counteract that of the engine.

Never overload a belt that is not in sight, as there is constant danger from fire.

A good leather belt, well cared for, ought to last for 10 or 12 years, though there are cases on record

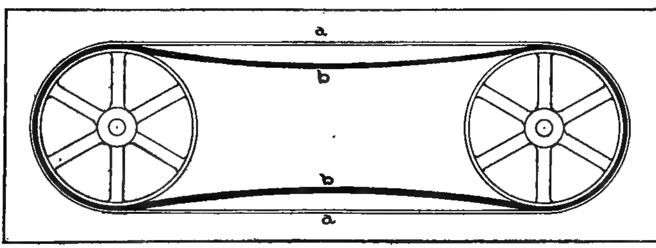


FIG. 106.—A Useful Kink. Driving Belt Loose, But Kept in Contact With Pulleys With Lighter, Narrow Binding Belt.

where they have been kept in continuous service for 18 or even 20 years. A belt working under moderate load and over well set pulleys will last much longer than otherwise.

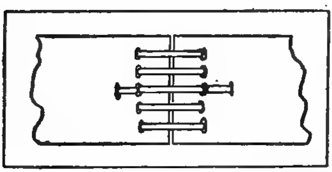
A crossed or twisted belt is sometimes necessary for reversing the motion. If the pulleys over which it works are nearly alike it should increase the arc of contact though it adds to the friction.

435. **A Useful Belt Kink.**—The drawing power of a large belt may be materially increased and the strain on both the belt and the journals greatly diminished by running decidedly loose and at the same time holding the belt snugly to the pulley surfaces by running a small binder belt outside of it (Fig. 106). The lat-

ter should be drawn tight. This permits doing away with most of the tension without diminishing the grip of the main belt on the wheel face.

436. **Belt Lacing.**—A good belt should have but one joint, and even that, where practicable, had better be dispensed with. Endless belts are only available, however, where one of the pulleys over which they are to be used may be moved up or back at will, as a belt will stretch and, when made to fit between two wheels at the beginning, will soon become too long for the place, and have to be taken up.

To lace a belt, first cut the ends off square across so that the tension will be even. Cut the holes with



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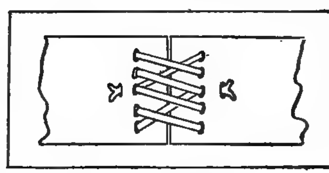


108

FIG. 107.—The Finished Joint, Pulley Side.
FIG. 108.—The Finished Laced Joint, Top of Belt.

a belt punch, and a sloping, shearing cut gives smoothest edges. One row of holes is enough for light work and two is plenty for the heaviest work around the farm, though three are sometimes used in running heavy machinery. The lacing should be done so that an equal strain is placed on all the holes and none of the laces either twisted or crossed on the pulley side of the belt. The laces will not wear out nearly so fast and will not jerk the machinery so much. An oval punch is best with the large diameter turned lengthwise of the belt. Many belts are ruined by large holes or holes too close together. The latter makes a stronger lace but weakens the belt.

If a six-inch belt or less is being punched, mark a line square across each end one inch back, and along these lines lay off the places for the holes exactly opposite each other and with equal spacing between. An odd number of holes in each row works out best. For a larger belt and for heavier loads use a second row of holes the same distance back of the first. The distance apart and from the ends may be increased a little for wide belts and diminished for narrow. Canvas belts should be punched with a pointed instrument that will shove the fibers aside instead of cutting them off. For leather or rubber, a smooth cut is best and the hole should be large enough to pass the lace through twice without straining the fiber of the leather.

437. **Lace Leathers.**—Rawhide is used for lacing, and it may be purchased already cut or by the side, and then cut up by hand. The latter method is much the cheapest, but the strips should be cut straight, smooth and even in width. A lace that varies in width is an abomination. When buying those ready cut, select those of medium and uniform thickness in preference to extra heavy or light. The first are not flexible enough; the second lack strength. From five-sixteenths to a half-inch is the usual width, the former being preferable excepting for the heaviest belts. If the smooth or hair side of the lace is placed out it will wear longer. By wetting the ends and then burning them until slightly crisped they may be put through the hole more easily.

438. **Methods of Lacing.**—To double lace a single row of holes, begin at the center of the belt and, with the pulley side below, pass each end up through the center hole in each end of the belt, then down, the one to the right and the other to the left, through the

next hole in the opposite end of the belt. Continue this until the edge is reached, then turn and lace back through the same holes. When the edges of the belt are again reached each hole will have two laces through it, all of the crossing will have been done on the upper side, and the ends of the lace will also both be at the top. Instead of tying these, poke the ends through under one of the other laces and then carry them down through smaller holes that they will fill snugly, and cut them off with the ends a very little beyond the under surface. The pressure of the pulley will soon settle them into place. The two sides of this lace when finished will, if rightly done, look like those in Figs. 107 and 108. Short pieces of lac-

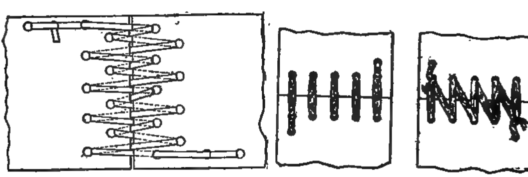


FIG. 109.—Several Methods of Belt Lacing.

ing drawn in over the main piece where it wears upon the pulley will increase the life of the lace but it also adds to the jar of the belt in passing, and decreases the surface of contact at the instant when it is most needed. Other methods of lacing are given in the illustration (Fig. 109), from which they may be easily worked out. Hinge lacing takes less lace than some of the others and has the advantage of drawing upon the body of the belt between the holes instead of directly on the hole. For this reason it is specially good for old rotten belts; also for rubber and web belting. Bootleg lacing does not come in contact with the pulley at all, and for cotton or badly frayed rub-

ber belting is cheapest and makes the smoothest running belt. It looks bungling and unworkmanlike, however, and is somewhat dangerous to operators, and is little used.

Never allow several inches of free lace ends to whip about the machinery. It is constantly catching and straining both lacing and belt, and is dangerous to operators. Cut the ends off or tuck them under.

439. **Wire Lacing and Belt Hooks.**—Wire lacings when properly made are quite durable and give little jolt at the joint, but their efficiency depends a good deal on the lacer. The holes may be much smaller;

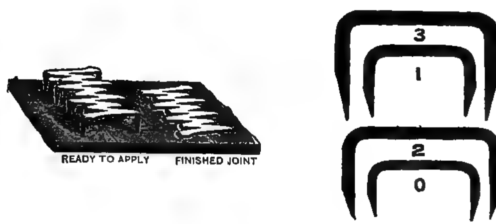


FIG. 110.—Some Approved Metallic Belt Hooks.

just large enough for the wire to pass through twice. They are fastened by flattening with a hammer. They are specially intended for leather belts and are also used for canvas. Wire lacing should never be crossed on the pulley side of the belt. Belt hooks and other metallic fasteners are convenient to apply but some of them lack flexibility and should specially be avoided with small pulleys. Some of them work well when in good condition. A broken and projecting belt hook may become a very dangerous thing.

440. **Cementing Belts.**—But for the one difficulty of stretching, the cemented or spliced belt would be ideal for leather, but unless the distance between jour-

nals or the size of the pulleys can be varied, such a joint should not be made until the stretch has been taken out of the belt by a period of use. A joint of this sort, if well made, is permanent and is supposed to wear as long as any other part of the belt, and it runs over the pulley without jerk or vibration.

For a six-inch belt or smaller, cut the belt six inches longer than for lacing; mark off six inches from end and taper with plane or spoke shave. Do the same with the other end but on the opposite side. Scrape the laps with steel or glass to make them even. Have a smooth surface under belt while splicing. After cutting, place belt on pulleys and draw tight, with the joint at some point between the pulleys. Hold a board under joint and nail belt to it with small nails to insure again slipping. Remove belt and board to a convenient place and apply belt glue (not common glue) hot. Apply this to both ends of the lap, then place together and hammer lightly for a few minutes to expel all air. Glue a strip of paper over the tips of the leather to keep them in place until the work is thoroughly set; then clamp tightly together for a few hours. The laps must be kept clean while gluing.

441. **Splicing a Gandy or a Canvas Belt.**—For a six-inch belt make the splice about four times the width of the belt and lay off the splice into as many equal parts as there are layers in the belt. Cut one ply off the entire length, the second at the next point of division, and so on; then do the same with the other end but work from the other side of the belt, so that the longest ply in the one end will come opposite the place where the full lap was cut off in the other.

Fit the ends together and sew lengthwise of the belt with waxed thread, the seams about one inch apart.

An occasional coat of linseed oil and red lead will prolong the life of a Gandy belt materially.

442. **Rope Transmission.**—Where the power has to be transmitted considerable distance and a variety of directions, cotton, manila and hemp ropes over grooved wheels or sheaves are becoming popular as they wear longer, are more flexible, less costly, and transmit more power than belts. Their motion is also very smooth and noiseless. The speed should be around 4,000 feet per minute; never over 5,000, and the smallest pulley should have a diameter at least 30 times the rope. Rope drive may be used even if the shafts are not quite parallel and, on account of greater contact in the wedge-shaped grooves, they may be run more loosely and with less slip. There should be a distance of at least 20 feet between pulley centers. Worn rope, once it begins to roughen, is very troublesome and should be replaced. An occasional dressing of beeswax and graphite will add much to the life of a rope drive.

CHAPTER XX.

OTHER FORMS OF TRANSMISSION.

443. **Gear Wheels.**—In spite of its defects gear-wheel transmission will probably be in use so long as it is necessary to transmit an absolute motion, no matter how much the load varies. With it there is no stretching or slipping of belts. Whatever the overload the motion will be transmitted so long as the driving wheels revolve unless the gear is stripped. It is also a convenient means of cutting out or reversing or changing speed, though lately the friction clutch has in part usurped this field. In using this form of transmission, however, one must remember that as the power is faithfully transmitted, so is any unsteadiness in it likewise, together with more or less vibration originating in the gear itself. Overloading is more unsafe, too, than with belts, because there is no slippage to guard against a serious strain. With the belt, something gives; with the bearing, it breaks.

444. **Material.**—Gear wheels are made of brass (for small work), iron, steel, bronze and raw hide. They vary in size from the finest pinion of a watch to mill machinery weighing many tons. On account of their absolute transmission under variable load, they are specially well liked for traction engines.

445. **Finish.**—Iron gear wheels are made to certain specifications, recognized as standard by manufacturers. To depart from this is not only to insure

greater cost on the first special order but on all subsequent repairs and possibly some difficulty in coupling up with other machinery. Iron wheels are either

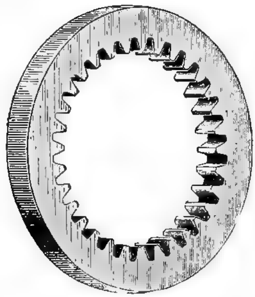


FIG. 111.—Internal Spur Gear.

cut or cast, the latter being cheaper, and the cut gear much the smoothest and most desirable for fast running wheels, or where an even motion is desired. For

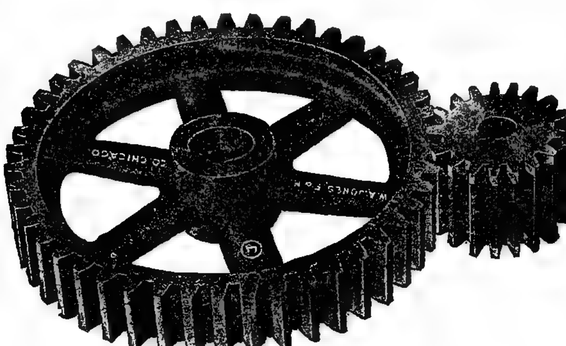


FIG. 112.—External Spur Gearing.

the rougher work, and with slow moving machinery, the cast wheels will often answer. Many farm machines use the cast gear, though some of the finer sort, like the cream separator, require the cut.

446. Spur Gearing.—Spur gears, the most common of all in use, are those which turn on parallel axes, without regard to the form of teeth. They may be

FIG. 113.—Bevel Gearing.

either within the rim of the driven wheel, as in the main drive wheels of some mowers and of most tractors, or around the outer side of the rim, as in

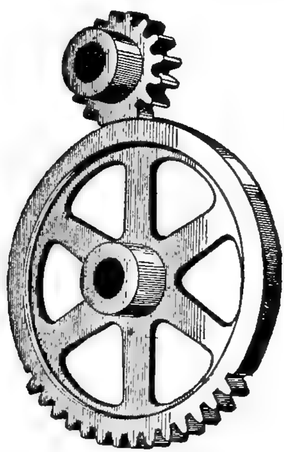


FIG. 114.—Intermittent Gears.

most of the intermediate transmissions. Fig. 111 illustrates the first type, and 112 the second.

447. Bevel and Miter Gears.—If the axes of a pair of gear wheels meet at an angle they are called bevel gears; if they meet at a right angle and the gears

are equal they are termed miter gears. All miter gears are bevel, but not all bevel are miter gears. They are used when the direction of the power transmission must be changed (Fig. 113).

448. **Intermittent Gears.**—Intermittent gears are occasionally introduced into the timing system of a gasoline engine, but are not in common use in farm machinery. Their purpose is to transmit power while turning a certain distance but not continuously. Most engine timing is done by means of cams (Fig. 114).

449. **Cams.**—Cams are a species of gear peculiar in that they are fashioned on the principle of a wheel

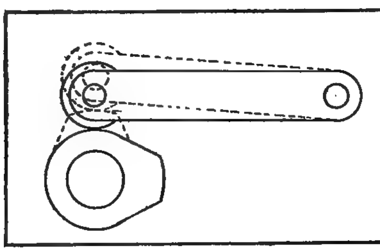


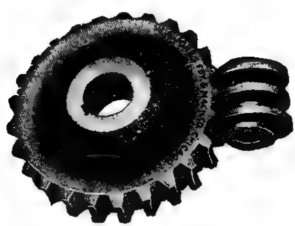
FIG. 115.—Action of Cam Outlined.

turning on an axis not at its center, in order that they may press more firmly against a near-by lever or spring at one time than another. Often their shape is such a departure from that of the true wheel that they bear little resemblance to it (Fig. 115).

450. **Worm Gear.**—Worm gearing is in very common use in the guiding systems of tractors; the power applied by the operator to the hand wheel being transmitted to the front axle through a worm gear. They represent a very great reduction of speed applied and distance covered by the actuating energy but add greatly to the power, combining as they do the lever-

age principle of the wheel and the inclined plane (Fig. 116).

451. **Other Gear Wheels.**—Some of the other commoner forms of gearing are the sprocket wheel, ratchet wheel, escape wheel, crown gear wheel, spiral gear, rack and pinion and elliptic gear. Most of them are found in farm machinery so seldom that their special description is unnecessary. Cog wheels, the name under which all gear wheels erroneously pass with many people, are wheels into which the gear teeth are set in separate pieces. They are seldom seen



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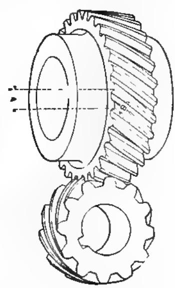

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FIG. 116.—Worm Gearing Used In Tractor Steering Gears.
FIG. 117.—Spiral Gear Used for Cam Shaft Operation.

on the farm and are only referred to because so often confused with gear wheels.

452. **Rawhide Gearing.**—One of the objections to iron gear wheels has always been the noise they make. To obviate this, other substances as fiber, leather, etc., have been tried. Leather has been found specially successful after being subjected to special treatment but is rather expensive for large wheels. It has been found that an iron wheel meshing with one of leather does away with most of the noise, so leather is often used for the small wheel or pinion to mesh with

one of iron much larger. For a specially silent gear the face of the rawhide gear is sometimes made slightly wider than its metal mate and, to guard against curling over, brass flanges are bolted securely to each side of the wheel, including the teeth. This adds somewhat to the cost and a great deal to the life of the gear.

Even when badly worn, a leather gear wheel retains its elastic nature and continues to transmit power without vibration or jar and so materially increases the life of its metal mate. It is not desirable in places where it is likely to become wet and not in connection with irregular motion or with cast gearing, the irregular shrinkage of the latter, in cooling, making too much unequal strain because of the rough surface.

453. **Care of Leather Pinions.**—Do not use mineral oil on rawhide pinions as it tends to soften them and they usually get all the oil they need from their bearings. Instead, coat the surface with a dressing of graphite and hard grease.

Never allow the bearings to become hot. Leather is an animal substance and may be consumed.

Store them, when not in use, in a cool, dry place and cover the rawhide slightly with the hard grease and graphite mixture.

See whether the teeth are meshing properly. Failure to do this may ruin the pinion in a very short time.

454. **Rules Governing Gear Repairs.**—The outside diameter of a gear wheel is taken from the circle made by a line drawn around the outside tips of the teeth.

The pitch diameter is taken on a circle through the point where the teeth roll into working contact with those of another wheel.

Diameter, applied to gearing, always means pitch diameter unless otherwise specified.

The diametrical pitch is the number of teeth to each inch of pitch diameter. The pitch of any standard wheel may be obtained by dividing the number of its teeth by the number of inches in its pitch diameter.

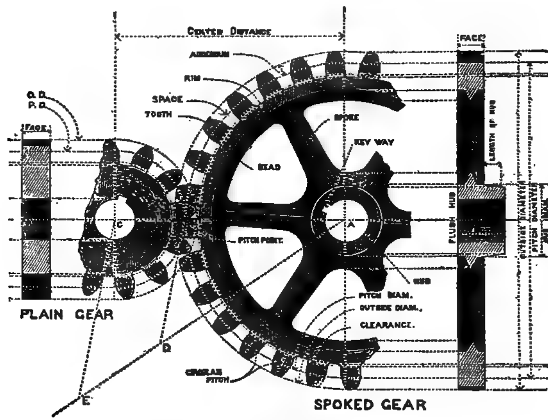

FIG. 118.—Illustrating Terms Used In Ordering Spur Gear Wheels.

The pitch of any standard wheel may be obtained from the outside diameter (which is more convenient to measure) by adding 2 to the actual number of teeth and dividing by the outside diameter. From this the pitch diameter may be found by dividing the number of teeth by the pitch.

Circular pitch is the distance from center to center between the teeth measured along the line of the pitch circle. It may be obtained by dividing 3.1416 by the diametrical pitch.

The above rules will enable any one to calculate for themselves by counting the teeth and taking the outside measure of the wheel those commoner specifica-

tions which are necessary to know in ordering gear wheels that will fit other gearing.

The length of a gear wheel hub is its projection beyond the rim and not from the spoke. It is much better to state the length of the hole instead of the hub.

To find the size of a gear wheel needed upon a fixed shaft to mesh with a certain gear wheel on a second fixed shaft, measure the distance from center to center, between the two shafts in inches, double the distance and multiply by the diametrical pitch (as obtained by means of rule already given from wheel on shaft), and from the quotient subtract the number of teeth on the wheel given; the result will be the number of teeth in the wheel to be obtained. With this and the diametrical pitch, which is the same as for the other wheel, all the dimensions of the new wheel may be worked out.

Whenever the term "pitch" is applied to gearing it is understood to mean diametrical pitch; that is, the number of teeth to each inch of pitch diameter.

The above rules are for spur gear calculations. Those for bevel gear are considerably more complicated and of less general use.

455. **Power of Gear Wheels.**—The horse-power that a certain gear wheel will transmit depends upon four things; the face, the pitch, the velocity of pitch circle in feet per second, and the kind of wheel, whether spur, or bevel. To find the velocity multiply the pitch diameter in inches by the number of revolutions per minute and divide the product by 230. At a velocity of 6 feet per second a spur wheel with 1-inch face and 1-inch pitch will safely transmit 2.782 horse-power and each trebling of velocity for the same wheel will a very little more than double the power.

If the pitch and face are more or less than one inch, multiply the power given at the required velocity by the number of inches or the fractional part of an inch, and that result by the number of inches of face. This gives the horse-power transmitted. In practice under average conditions but half or two-thirds of this result should be expected.

The velocity of gearing should be kept below 2,200 feet per minute for iron gear and 3,000 for wood and iron.

456. **An Ideal Gear Wheel Order.**—If the following specifications are given there should be no excuse for any supply house failing to send the wheel wanted.

1, material—2, outside diameter—3, pitch diameter—4, face—5, bore—6, number of teeth—7, pitch (diametrical or circular)—8, diameter of hub—9, distance through hub—10, projection—11, distance from center to center of shafts.

When ordering spur gears to transmit a certain horse-power give the number of revolutions per minute, size of shafts or bore, and largest and smallest allowable diameters.

Bevel gearing will transmit approximately ¾ the horse-power safely conveyed by spur gear.

The above calculations are for involute teeth, which are now more popular and in far more common use than the epicycloidal pattern, one advantage being that they do not require such accurate adjustment.

457. **General Care.**—Transmission gearing requires occasional attention quite as much at its rim as at the axle, and this is particularly true in relation to the tractor gearing, especially the differential. Grease, oil, graphite and reasonable cleanliness, at least freedom from the grit of road dust and ground-up pebbles, will cure most of the ills it is heir to, old age

excepted. The proper use of the clutch might also be urged here. More gearing has unquestionably been stripped by sudden than by excessive strains.

Noisy gears may sometimes be silenced by cleaning thoroughly with kerosene or gasoline and then packing with medium grease to which flake graphite has been added.

Worn gears should be replaced promptly as they are a constant source of annoyance and even danger. The strain of any sudden emergency hunts out the worn tooth with unerring accuracy and a broken gear or pinion is likely to set some of the others to stripping. Worn gearing does not mesh properly and not only causes considerable loss of motion or power through slippage, but wears more rapidly, once the proper relation between the wheels is disturbed.

A temporary remedy for worn and noisy gearing is a handful of sawdust. This, of course, is a makeshift only. Thick grease and French chalk are also of considerable use. Worn gear teeth are noisy because they strike against each other instead of rolling.

CHAPTER XXI.

THE FEED-ROOM.

458. When Feed-grinding Does Not Pay.—There is a great difference of opinion as to whether the grinding of feed is profitable under the usual conditions. That it is beneficial no one doubts. Whether

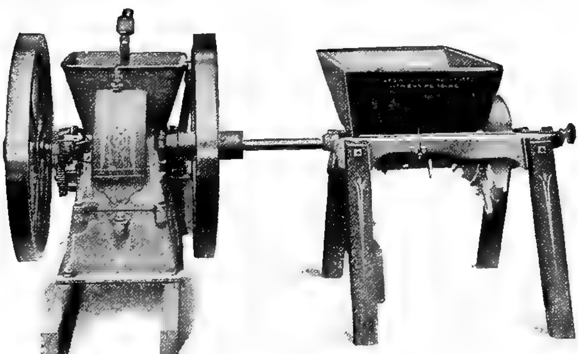

FIG. 119.—Feed Mill With Direct Shaft Drive From New Holland Engine.

the benefit is enough to justify the double handling of large quantities of grain, of hauling it, perhaps over bad roads, several miles to the nearest mill and then back again, and of the expense in cash or toll for grinding is an open question. Often it is cheaper to let a part of the grain be wasted by being fed unground than it is to put so much extra work and expense into the grinding.

459. **Convenient Grinding.**—With a gasoline engine properly installed this waste of the farm crops at the feed bin is unnecessary, nor is any great amount of extra work called for. A link-chain conveyor or elevator, run by the engine, should carry the grain in a constant stream from a portable bin or trough set beside the thresher to elevated bins in the feed room above the stables. Below these bins, and connected to its hopper by closed wooden spouts, should stand the feed grinder, belted to a shaft or directly connected with the engine. By opening slides in one or more of these spouts a stream of any grain stored in the bins above or a mixture of any two or more is conveyed directly into the hopper without a pound of grain having to be lifted with human hands. The attendant may then start the engine and, once having thrown the mill into operation, need give it no further attention until the grinding is completed.

460. **Convenient Feeding.**—The discharge from the mill may be conveyed to a bagger or directly into a portable bin supplied with wheels and shafts, and which is easily moved along the row of feed chutes leading into the feeding boxes in the mangers below. From the time the grain leaves the threshing machine it need not be touched until it is stored, ground, mixed in any desired proportions and delivered to the hands of the feeder directly over the animals in the stable below. All lifting is avoided and all carrying. The engine and gravity do it all; but only the work of the engine renders it convenient to elevate the grain where gravity can be used.

461. **Feed Always Fresh.**—Ground meal, if stored in quantities, is far more likely to taint, heat or become infested with insect enemies than the whole grain. No matter how well seasoned the corn, there

is always so much risk in the continuous storing of corn meal in quantities that constant watchfulness is necessary; often frequent handling. Still, if the grain has to be hauled some distance to a mill or if it is worked up on the farm with a steam power grinder, there is little economy in grinding it in small quantities.

With the gasoline engine feed may be ground fresh as needed, while the water is being pumped or the morning chores done. Little attention is required. All mixtures, too, may be regulated when the slides are opened so that the nature of the feed is changed, without any trouble, to suit conditions; or a different mixture may be provided for different lots of cattle or even for different individuals. It is no longer necessary to have storage bins for the mixtures best adapted to the dairy cow, the horse, the growing calf, nor are we compelled to feed the same mixture to all alike without consulting the purpose.

462. **The Balanced Ration.**—The farm feed mill and the power which can be made available at any time without fuss lend themselves specially to the compounding of balanced rations best suited for any specific purpose or for several of them which may be served all at once.

463. **A Good Feeding Plan.**—Most animals are inclined to bolt their grain and then pick over their roughage very gingerly, selecting only the choicest portions and tossing the rest upon the floor to be wasted. Hay thrown to them in bunches and separate from the grain rather invites a playful attack with the horns and a tendency to cull it over with too much discrimination, while the grain, fed alone, is eaten too fast.

If the hay or fodder is first run through a feed

cutter or shredder there is almost no waste. It may then be fed in tight boxes and, by being mixed with the grain and fed all at once, it is all eaten and at the same time the grain is not swallowed so hurriedly, nor does it reach the stomach in a compact mass. The actual quantity being fed is more handily determined, too, either by the scales or by measure, and there is far less likelihood of feeding entirely by guess. Taking into account all of the leaks which accompany the old method of feeding, there is here an increased efficiency of from 25% to 40% in the actual feeding value of the same hay and grain.

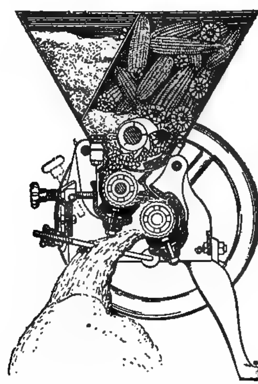

FIG. 120.—Mill for Grinding Two Kinds of Grain.

464. A Special Appetizer.—The addition of water in reasonable quantities does much to freshen up the usually dry, hard feed of the winter months and a small handful of salt adds not a little to the relish. Three minutes with the spray pump over the mixing bin prepares the cut hay specially well not only to be relished by the cattle, but also moistens it enough so that the ground feed scattered over it is eaten at

the same time, and does not sift through to the bottom of the manger.

465. **Grinding Cob Meal.**—The cob meal attachment should not be forgotten when the home grinding mill is run. It is true that there is not a great deal of nutrition in the cob itself but when reduced to a coarse meal it serves well as a mechanical mixture and helps lighten up the heavier portion so that

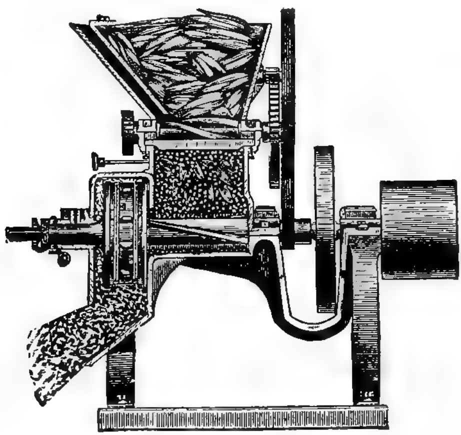

FIG. 121.—Power Driven Mill for Grinding Grain, Cob and Husk.

it is better exposed to the action of the gastric juices. Cobs are rather hard to grind and the average miller will not grind them except for an extra price. Besides, they are bulky and that much more of a load to haul over the roads, when taken away. Worked up on the home mill they are worth at least the extra power they take, and well repay the little attention they require, even though they feed a little more slowly into the hopper.

466. **Grinding Family Grists.**—By adding only a

few dollars to the first expense of the mill one can be obtained which will do first class work on corn meal, graham flour, and whole wheat flour for family use. The grist obtained is at least a good ways ahead of some that is furnished when grain is taken in exchange by the village miller and stored meal supplied. The home grist is always fresh and every man who takes enough pride and care in his farming to produce first class grain is certain of being rewarded by meal from his own instead of from that raised by some careless neighbor.

467. **Accessories of the Feed Room.**—Good feed alone is not the only subject of importance to the feed room nor is it the only one wherein the gasoline engine plays a most important part. Actual experiments have proven that where water is supplied to dairy cows at stated intervals of twice daily the milk yield averaged 225 pounds less per annum than where they were allowed to drink at will. As nearly half the animal weight of the fat ox is water it is evident that drink should play an important part in the fattening of beef cattle as well as in their growth and development. It is safe to say, though, that for every stock barn equipped with a continuous watering device there are hundreds wherein cattle are watered less than twice daily; in fact, the average general purpose farm is conducted on the single-watering plan.

468. **Objections to the Continuous Water Supply System.**—Ordinarily there have been several objections to attempting to maintain a constant water supply. First, running water is not furnished by nature at every location, while we are becoming more and more suspicious of that which is, as a possible source of contagion. Storage tanks of sufficient size to supply constant running water are expensive, in

the way and, to a certain extent, dangerous. To run the troughs full of water once or twice daily is to invite a mixture of dust and hay stems in the water that, in the process of drinking, the animals are liable to draw into the wind-pipe, while much of the most nutritious part of the hay finds its way into the watering trough to be drawn off and wasted whenever the trough is cleaned. It is always objectionable, too, for water intended for stock to be exposed to the breath of stabled animals on account of the vapors absorbed by it.

469. **Constant Renewal Necessary.**—No system of stock watering is successful which does not supply the animals with fresh water whenever it is supplied at all, without having to resort to any extensive storage system. A small reserve supply is not only allowable but necessary; but the system which depends on great quantities of storage water exposed to the dust and odors of the place is never suitable.

470. **The Gasoline Engine a Necessity.**—Excepting in some few highly favored localities, some form of dependable power must be at hand which is so easily applied that we may safely rely upon direct pumping, with scarcely any storage provisions of any kind. A small pressure tank, though, is a great addition, in the absence of which a closed storage tank holding two or three barrels of water will answer nicely. Whichever is used, an indicator must be attached to regulate the amount of pressure in the one case and of water in the other.

471. **The Open Trough.**—The simplest method of getting the water constantly before the cattle is to run it directly into one end of a continuous trough and allow it to drain out at the other. This consumes lots of water; all the objections urged against the

old style water systems may be raised against it; while those cattle at the end most remote from the inflow are entirely dependent for their own supply upon the caprice of all the other animals in the stable.

472. **Automatic Troughs.**—There are several styles of individual automatic troughs upon the market that are satisfactory, though some of them are rather expensive to install. The water is under very perfect control though, and all that is stored ahead is confined in air-tight pipes which protect it from dust and stable odors.

473. **A Home Made Substitute.**—For the drinking wells a row of ordinary granite wash basins are not at all bad, although a dish measuring a little less in diameter would be somewhat better. These are all fitted snugly into wooden seats or collars that hold them rigid and distribute the strain well over the bottom and sides of the basin. It is but to so arrange them that they may be easily removed for cleaning whenever desirable.

Behind these and supported to the back of the manger, an inch or inch-and-a-quarter pipe serves as the main conductor, and from it a half-inch (or less) tee located opposite each basin permits water to escape through a discharge pipe coming up over and then down into the basin. The main pipe should be so placed that the top surface of the water it contains is rather less than two inches above the bottom of the basins. This insures about two inches of water always in each basin, a quantity so small that the arguments against standing water do not apply to it with any great force. One draught of the animal empties the basin and starts the water to flowing in until the level in the pipe is reached again. At night

and in cold weather the main pipe may be drained by a spigot at the lower end, or a small stream left running, and all danger of freezing is avoided. Perhaps the gasoline engine does not seem to have a great deal to do with this system but in the majority of barns the plan would be impracticable were it not for some power that could be called upon readily and that would always respond.

474. **Advantages of This System.**—Aside from the benefits of a constant supply of unpolluted water, there are several other advantages. The supply comes rather slowly to each animal, if the discharge pipes are small, and rapid drinking is discouraged. The water, pumped from far below the surface, is freer from contagious influences and dangerous germs of all kinds. It is practically never exposed even to the air from the time it leaves the well until it is discharged into the animal's basin. Neither does one animal have to drink what another has left. There is no danger through the transmission of disease from the drinking water and a well balanced system with a capacity reasonably tempered to the size of the herd admits of no contaminated water finding its way from any herd to any near-by stream. The amount of water which enters this system and escapes it save through the stomachs of the animals is so small that it filters into the earth and is purified before finding its way to any natural channel. The matter of temperature, too, is of considerable importance. While it has not been found advantageous to regularly heat water for animals, it is none the less injurious to them to be compelled to drink that which is far below the normal. A milch cow promptly shows this in shrinkage of milk. The effect is just as serious to the beef animal, only the latter is not sup-

plied with a natural thermometer that we can read as readily as we can the record of the milk pail. Water pumped from deep in the earth and not subject to any great change of temperature, winter or summer, never chills or shocks the sensitive nervous system of a cow, while that which varies with the weather is almost sure to do so.

475. **The Work of the Engine.**—Any watering system which depends upon anything but gravity or some form of natural delivery must have back of it a source of power which is actually dependable; one that can be used whenever needed, and one so convenient that it will be used. Without such a power, meaning the gasoline engine in most cases, watering systems like this would be worse than useless, because, once depended upon, if something went wrong with them suddenly, their very completeness at ordinary times would make us forget to provide against possible failure.

476. **Flushing Out the Gutters.**—One form of gasoline engine efficiency in the stable has never been appreciated as it should be, excepting by the few who have the system in operation. That is in the flushing out and better cleansing of the gutters and the application of the manure upon the fields in its best form.

477. **Stable Arrangement Necessary.**—In order to adopt this system it is necessary that the stable be provided with good gutters, either cement or wood; then it is the work of the engine to supply plenty of water and good pressure, either direct from the pump or from a pressure or storage tank. One other duty the engine must perform as already referred to; the chaffing of all the hay, fodder and bedding used in the stables.

478. The Flushing Process Easier and More Sanitary.—Instead of scraping out the gutters with a fork or shovel and leaving every crack and depression reeking with filth and germs, both gutters and floors are washed clean by means of a hose, with water under pressure. The work is done more quickly and thoroughly than is possible in any other way, and the process is far more agreeable to the man who does it. Everything is either reduced to a liquid form or at least held in suspension until it can be removed from the stable; while every crevice, no matter how small, is searched out and thoroughly cleansed, instead of being left to ferment and form a harbor for vermin and disease.

479. Final Disposal on the Fields.—From the end of the gutter the liquid is conducted by any convenient method directly into a tight manure vat or tank, which is mounted on wheels. This should be provided with some sort of agitator operated by means of gearing, to insure against the undissolved particles settling to the bottom of the tank. When hauled to the field the contents may be far more evenly distributed through a coarse sprinkling attachment than the best spreader can do under the most favorable conditions, while there is none of the hard lifting ordinarily required in loading up.

No other method of stable cleaning is so free from lifting or unpleasantness. No other is so economical in the application of the manure upon the field. No other method gets it into the earth as a plant food so quickly, all through the water and the pressure, which the engine supplies.

CHAPTER XXII.

THE WORK-SHOP.

480. **Its Purpose.**—The farm work-shop is required for two purposes; for making things and for repairing them. Of the two objects the last is undoubtedly of greatest importance. Because of his greater remoteness from the town or village shop, the farmer must always depend more upon his own skill in keeping his tools in order than his city brother has to do; and a good farm repair shop, with a good man back of it, always means better kept farming tools, more conveniences, more efficient work and better farming.

481. **As Trouble Healer.**—The great mission of the farm repair shop is in the prompt removal of possible trouble before trouble itself comes. When the repair of a weakened part means a trip to town, there is a tendency to continue using it as it is so long as it holds at all; then it frequently gives way in the midst of the very busiest time, when it is being put to the greatest use, and often with disastrous results to the entire machine. We do not like to spend too much time and money making repairs until we see for a certainty whether the part is ever going to break or not. With our own work-shop handy though, and well enough equipped to be efficient without adding to our drudgery, the first rainy half hour will probably see the part made good as ever, and save an expensive breakdown.

482. **A Good Equipment.**—Almost any farm pos-

sesses a grindstone, an emery wheel, perhaps a lathe and a saw arbor. All of these are valuable only as they are made use of. When their use means an extra session with the tread mill there is a human tendency to postpone work that might, if promptly done, increase the efficiency of our regular work. Even a grindstone may easily become a source of drudgery to some one, usually the boy of the farm. Anyone who has ever turned one by hand for an hour at a time appreciates the tendency to slight the grinding of the mower knives or to let the axes and hoes go with less keen edges than they ought to carry. The emery wheel loses much of its efficiency unless speeded up well; while the farm lathe must either be too light for real efficiency in order to keep within reasonable foot power limits or it is certain to have weeks of rest that it has never earned.

483. **The Engine in the Work-shop.**—The gasoline engine in the farm work-shop is out of place; it has no business there. Connected to the end of a line shaft running the work-shop machinery it is the ideal power, but the union should be neighborly only, not domestic. Emery dust, grit from the grindstone, even the floating particles of wood, notably cedar, have an abrading tendency, which is disastrous to the engine cylinder; while we have already seen that nothing is more disastrous to the valves than particles of shavings or an accumulation of light dust of the air drawn through the carburetor.

484. **The Proper Place.**—The proper place for the gasoline engine is either in an enclosure adjoining the work-shop or with a good tight partition to protect it from the shop air. It must be belted to a line shaft anyway, in order to allow us to start and stop any machine in the shop at will. There is no neces-

sity for having it in the same room the machines are in.

485. **An Ideal Shop Arrangement.**—The shop itself should be equipped with a good roomy bench along one side, the lower part of which may contain a system of drawers and cupboards for the convenient storing of the bench tools; or a near-by cabinet of drawers made from boxes of one size may be preferred. If the shop is in the barn, the position of

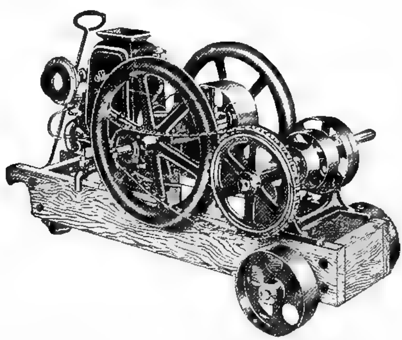

FIG. 122.—A Handy Shop Engine, Equipped With Countershaft and Three Different Sizes of Driving Pulleys.

the power shaft must be determined by that of the engine, which will, of course, be the same one which provides power for other barn work. If a separate shop is to be built, it should be quite long in proportion to its width and, if located near the house, can well be arranged for a shop at one end and a laundry at the other.

486. **The Engine's Position.**—The engine should preferably be installed near the center of the building and one line shaft run the full length, near the ceiling. This gets the shaft out of the way better than any other location and prevents accidents. By

belting the engine to it near the center instead of at one end a good deal of torsion or twist is avoided. No matter how well the shaft is put up, if the power is applied at the end there is more or less of this twisting tendency, which in field machinery becomes side draft. The shaft may be so rigidly held that it will stay in place and do its work all right; still there will be considerable lost energy, consumed by the extra friction, and friction always means wear as well as work. For this reason the longer shaft can be run and two rooms equipped with power as easily as the shop alone, and at less cost of friction.

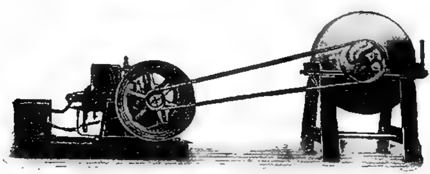

FIG. 123.—The Most Important Farm Implement.

487. Connecting Engine to Work.—For ordinary farm shop work a $1\frac{3}{16}''$ shaft will probably be the best size, although, if of considerable length, the hangers should be close enough together to insure against any possible tendency to spring. Remember always that a bent shaft requires the engine to bend or spring it into line by "main force" every time the shaft turns over, and when that is a good many times per minute it wastes a good deal of engine energy besides wrenching the machinery. The shaft may be equipped with tight and loose pulleys for each machine to be connected, or loose belts and tighteners may be used. The former are the best in most cases and they cost the most to install. For directions as

to size of pulleys and belts required, see chapters on Belts, Pulleys, etc.

488. Locating Machines.—Where convenient it is always best to install the heaviest machines, that is, those that require the most power, nearest the engine. Always remember that, no matter how rigidly

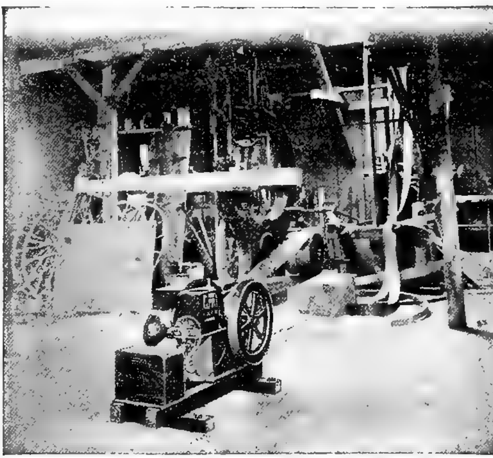

FIG. 124.—Gray Engine Driving Bandsaw in Wood-working Shop.

the shaft is held to its place, side draft or twist still remains in the line of working energy whenever the pull of the machine operated is at one side of the engine working line, and the farther to one side it is removed the greater is that strain. If a heavy lathe is installed it should be placed near the partition next to the engine room, while something of light draught, though of steadier use, should be reserved for attachment at the further end. Light machines, such as emery wheels, jig-saws, small cut-off saws, etc., may be located along the bench at the most convenient places. Among the light power machines

which should by all means be included in the work-shop equipment is a small rip saw suitable for ripping up plank. A six or eight-inch saw will be sufficient and a self feed equipment is not necessary. Perhaps there is no other single experience which will bring out the blessing of power in the work-shop so much as will one job of plank ripping with the circle saw in comparison with the old back-breaking laborious way.

489. **Effect on Man and Boy.**—The introduction of power into the repair shop will make so many

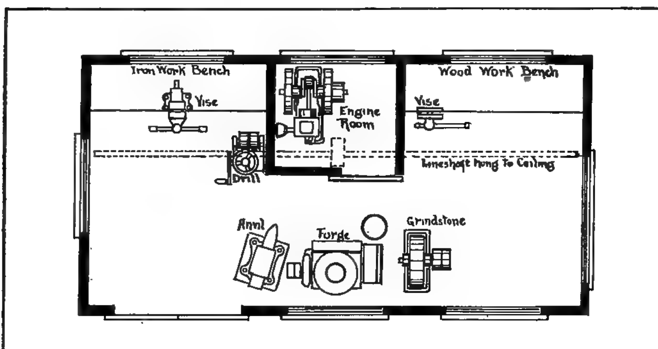

FIG. 125.—General Farm Workshop Floor Plan, Showing Good Arrangement of Machines and Housing of Engine In Separate Compartment to Reduce Fire Risk.

labor-saving machines available, that are not of much practical use without it, that the care and repair of the farm implements soon become a pleasure, instead of a dreaded task that has been in the past too often neglected. Then labor-saving devices will be studied out and made in spare minutes which will gradually make the equipment of the whole farm more complete, convenient and up to date. Gradually,

too, the habit of noting the condition of tools more closely will be formed, the little defects noticed and remembered as they come to us in our field work; and the defect will be remedied at the first leisure time. Without this observation habit, the weakness might have been forgotten as soon as the occasion for annoyance, because of it, had passed. In no other place more than the shop does the engine develop in the man and the boy the attention and thorough care of their equipment.

FIG. 126.—Sawing Wood by Gas Power Not an Irksome Task.

CHAPTER XXIII.

THE FARM WOOD-PILE.

490. **Two Memories.**—There are two memories, either in combination or one of them alone, which even yet disturb the farm boy of yesterday with dreams of cold fingers, backaches and frozen mittens—and always more of it ahead. One of them is flavored with the old cross-cut and its never-ending toll of hard work and spoiled half-holidays. The other is still accompanied by the grating ring of the neighborhood buzz-saw, which always meant weeks of strenuous log-piling and splitting in advance, a couple of days of almost killing work throwing the cut blocks of wood upon high piles, always hurrying to "keep ahead of the saw," or else "to keep the saw busy," and with the consciousness that there were days of this ahead helping the neighbors through similar jobs. Always, too, there was the consciousness that the very hardest part of this, the piling up of those great log heaps and the great stacks of wood, that all had to be undone again as time afforded, was labor wasted; that it was only necessary, because, in the hurry that the one or two day job of buzzing required, things had to be done the hardest way because there was no time for any other.

491. **A Thankless Task.**—Nothing is more discouraging than to do the hardest kind of work for hours or days, knowing all the time that it is absolutely resultless work and that it is only necessary

because of inefficient planning; that an easier way would be even more efficient. Those high piles of logs were required because, with the saw only available for a day or two and at a high cost for machine and men per hour, the material had to be at hand; but it meant that all of the hard lifting was only to be undone almost as soon as finished; that the big wood pile, builded up by one laborious swing of aching arms for each stick it contained was only a temporary affair, to be torn down again and hauled to the house as soon as there was time. All of the hardest work in the job was due to inconvenient and inefficient methods, but methods which, nevertheless, seemed the best that could be used.

492. **What It Really Cost.**—Much of that hard work was condoned by the thought that "the boys" were at home and the farm labor cost little or nothing. It probably cost many a farmer the help he afterwards needed from his grown-up boys, and it no doubt cost many a boy who was unfitted for the struggle for existence in the city, but who was driven from the farm by just such tasks, long years of disappointment; perhaps a ruined life. If we were to ask a number of farm-bred men who are now struggling in the congested cities, with more or less success, why they left the farm, it is likely that at least eight out of ten of them would think first of the wood-pile, the old pump, the grindstone and similar bits of every-day drudgery, before they would answer. It was just such tasks as these that convinced most of them the farm was only a big factory for turning out hard work and most of it of a hopeless, ineffectual kind.

493. **To-day's Wood-pile.**—Methods of that sort would be even more expensive now. Good farm labor

is scarce, and time is worth money. Then, too, the trees which were then only fit for fuel are plenty good enough for lumber now, while the material for firewood has to come from sources which would then have been despised. The straight-grained maples that split easily are no longer food for the buzz-saw. Instead, the wood-pile is replenished from the occasional windfall from which the best of the body wood has been removed for boards; from the scraggly apple tree; from the old rail fence. Not even boy labor would justify the time and teamwork necessary to handle these odds and ends of the woodlot in the way the "buzz wood" was formerly managed, and on many farms these are permitted to rot where they fall, because it costs more to work them up than to buy coal.

494. **Why Popular.**—The gasoline engine has made the wood-pile of to-day a popular place with the average healthy farm boy. It is worth a trip to the woods for a load of logs for the privilege of running the engine long enough to saw them up. The work does not have to be done at break-neck speed and it does not last so long that every muscle in the body is protesting; neither does the wood have to be thrown upon a pile that will presently all have to be torn down and piled over again. The wood is cut with the minimum amount of handling and all the work required can be efficiently applied so there is no dissatisfaction in the thought that it is energy thrown away. Enough logs can be hauled up for a reasonable run without having to lift them upon a high pile or drop them back too far from the work. Wood-cutting now is a glimpse of modern life, instead of drudgery and, if the boy should ever leave the farm, one of the pleasant memories that will occasionally call to him

will be that of the gasoline engine that he had to leave behind him when he went.

495. **The Circle Saw Rig.**—For cutting up limbs, old rails, tops and small logs, the circle saw still has

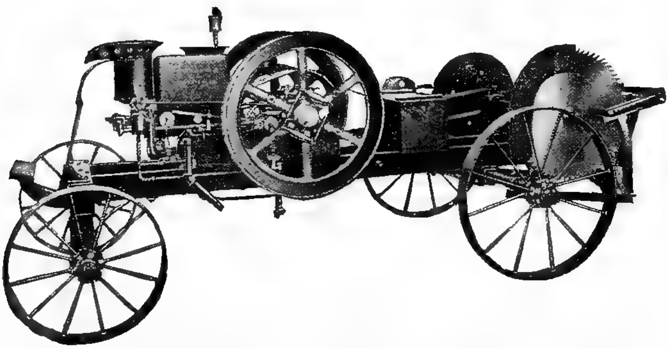

FIG. 127.—Gasoline Engine and Circular Saw Outfit in Portable Form.

the call, although the drag saw will require less heavy work, used in connection with logs of considerable size.

Any farm machinery supply house will furnish a good circle saw outfit, or one may almost make his own. There are several styles on the market, not different in general principle and only differing in those little details which mark the variety in personal tastes. A wooden or iron frame to hold the saw arbor and that may be anchored securely to some solid foundation; a tilting or sliding table; a four-foot steel shaft, 1½ inches or more in diameter and with saw arbor and flanges at one end; three babbitted boxes bored for bolting to the frame; a 100-pound balance wheel, a 6 x 6 or 5 x 6 crown-face pulley; a saw guard; these, with a 20 to 24-inch saw and a good two

or three horse-power engine will keep one or two men fairly busy; or, if the rig is turned over to the boys, it will cut more wood in the course of the afternoon than they would willingly cut all winter; two or four cords per hour being an entire possibility, providing there is provision for getting it to the saw and taking it away.

496. **Power Required.**—With a somewhat heavier engine, say a five or six H. P., a 28 to 30-inch saw may be easily run and, with a force of four men, 50 or 60 cords a day may be cut and piled. The fact remains, however, that on level ground there is considerable lifting to do. On the ordinary farm the smaller size is best; then the work can be taken in smaller doses and less unnecessary work in repiling will be required.

497. **The Best Rig.**—If the saw is to be taken to the work a traction rig is an advantage, or at least a mounted portable power. For this purpose one of the home-made tractors produced from the junk pile, at the cost of a few idle days and perhaps a dozen dollars, is just the thing. It will not be strong enough to draw a load behind, but may quite readily be made self-moving, which is all a wood sawing rig requires. Bolt the engine securely to the bed timbers over the drive wheels and the saw frame over the front trucks. Once bolted in place to the same timbers, there will be no bother about having to line up the engine with the rig every time it is moved.

498. **Setting Up.**—If convenient, run the rig below a bank upon which the logs can be hauled; then lay skids from bank to saw table. The rear end of the log may be held up by extending a part of the skids; or, better, support a steel rod on tripods and bolt upon it some form of track-door hanger or hay carrier that

runs upon a single rod. From this suspend a double rope, the one end reaching within a couple of feet of the level of the saw table and terminating in a few rather large links of chain. The other rope should be long enough to reach around a small log as it lies on a level with the saw table and should be provided at the end with a hook. The logs may then be hauled by team power upon the bank, rolled along the skidway until nearly upon the saw table at one end; then by throwing the rope about the other end, raising it slightly and catching the hook into the proper link in the chain and then rolling it from the skidway, a carriage will be improvised that will move the log forward as required with the minimum of friction and with practically no lifting. By rigging a 6 x 6-inch hard-wood timber upon supports and spiking regular door track along one side, two and even three hangers can be rigged which will not only support the entire log and allow it to swing free from all rigid supports, but would have the advantage of permitting it to swing against the saw with far less muscular effort than where a table is used. A permanent rig of this sort just outside the wood-shed will permit the running of the logs under cover during the actual sawing, the saw frame and engine being set inside. The work could then be done in stormy weather and the wood be stored in the shed as fast as sawed.

499. **The Drag Saw.**—For larger work the drag saw has a number of advantages. It handles logs of any size without turning and does not require that they be lifted up to it or shoved forward by hand power. Though slower than the circle saw, it can be arranged to go on working, once it is set and put in motion, and permit the operator to split or pile the blocks already sawed off, so there need be no time

lost. Considering the man-power it requires, a drag saw well set-up and operated will probably accomplish as much as the average circle saw, and do it with less previous preparation.

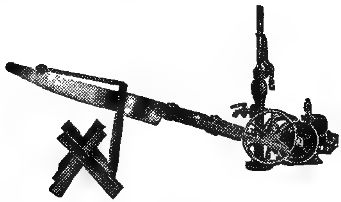

FIG. 128.—A Drag Saw Worked by Engine Power.

500. Construction.—Drag-saw frames can be purchased, or they can easily be made on the farm and the conditions under which they operate vary so much that this is often the best plan. Two 6 x 6 hard-wood sills should be tied together by three 2 x 8 or four 2 x 6 planks, which should be morticed in and bolted. Two 6-inch uprights, four feet long, should be securely bolted and braced upon one sill, with a two-inch block between at top and bottom. A small wheel fastened to a slide works freely up and down between these guides. This carries the weight of the saw frame and is raised and lowered by means of a rope carried over a grooved pulley to a lever. This may be arranged to hold the saw in place when lifted, by means of a quadrant, or merely with a hook, the weight of the frame being allowed to rest upon the log when lowered.

The pulley for the engine belt should be between the sills. This, in turn, belted to a countershaft, should reduce the speed of the latter to about 70 revolutions per minute. At one end of the countershaft, preferably at each end, if steady running is desired,

there should be a balance wheel, one of them provided with a crank-pin on its rim. A hard-wood arm, with a brass bushing at one end for the crank-pin, is clamped solidly to the saw at the other and works between the two four-foot uprights. If an ordinary cross-cut blade is used it should be made rigid by clamping an upright iron at each end to a slide arm 18 or 20 inches above the blade; otherwise there would be constant danger of a kinked or broken saw. Short legs should raise the machine just high enough to give the balance wheels room to revolve, though the shorter they can be the less will the log being sawed have to be raised from the ground. The diameter of the crank wheel must, of course, be the same as the desired sweep of the saw. The sills must be long enough for mounting the engine back of the saw rig, so that all danger of its shifting in relation to its work or the trouble of lining up is done away with.

In front of the rig construct a narrow log slide containing a series of rollers along the bottom and with a groove around their center sufficiently deep for a half-inch steel cable to pass over freely. This cable terminates at the one end in an ordinary log hook while the other passes the length of the slide through the grooves and around a grooved sheave at the end of the slide from which it goes to a drum revolving loosely on (not with) the shaft for the engine belt pulley. A taper or cone pulley, leather-faced, is mounted beside this drum which revolves with the shaft. A few inches of the shaft should be squared for the cone pulley to slide on and still revolve with the shaft in any position. This virtually makes a friction clutch and by means of a shifting fork the cone may, by being forced into the drum, lock it to revolve with the shaft or, by releasing the lever, the

drum will remain stationary while the cone and shaft are still rotating.

501. **To Operate Drag-saw Rig.**—The log to be sawed is rolled upon the slide, which is adjusted in width so that the weight rests upon the rollers in the bottom and the log hook at the end of the wire cable is driven into the end most remote from the saw. By means of a loose or friction pulley on the engine belt, the countershaft which runs the crank wheel and the saw is started and at the same time the blade is allowed to rest lightly upon the top of the log, the entire weight being gradually let down after the saw is in full motion. While the cut is being made the taper pulley revolves with the drum upon the shaft. As soon as it is completed the saw frame is raised clear of the log and stopped at the same time by releasing the friction pulley; then the shifting fork is made to crowd the cone into the drum and turn it with the shaft. This winds the cable upon the drum and so draws the log hook and log endwise along the slide toward the saw. For convenience a log stop or buffer should be set across the slide on the opposite side of the blade and this should be adjustable for any length cut desired. When the log advances until it strikes this stop, the shifting fork is reversed, the drum ceases to revolve and the saw may be let down and started as before. By locking the friction pulley to its place the operator can then leave the rig to itself, while carrying on other work, until the next cut is nearly completed. A well-made rig of this sort will handle almost any size log, without lifting or wasted work and it may be kept in such steady operation that the amount a single operator can do with it in a day's run is quite surprising.

502. **A Complete Automatic Rig.**—Occasionally it

may be found convenient for the operator to devote nearly the whole of his time to other work near by, such as splitting and piling up the wood as it is cut. If the work is close at hand and the logs not too rough to handle easily, this may be arranged by a little addition to the above rig.

The square portion of the main pulley shaft must be increased in length and for the single taper pulley we must substitute one that tapers at both ends and with a narrow ring or ridge running around its largest circumference at the center. If a pulley of this shape cannot be purchased one can be turned out of wood and rendered quite serviceable by having iron rings shrunk upon each end. These should be recessed in and should be flush with the surface of the wood. Both tapers of the pulley should be leather faced.

The same loose drum is used at one end. At the other a second drum is mounted, exactly similar to the first. These drums and the pulley between them are spaced so that the latter can be shifted to engage and lock either one at will; or it may remain at the center and neither of the drums will rotate. The one drum is connected as before with the cable that advances the log; the other with a similar cable, which passes over a grooved pulley at the top of the guide frame and so raises or lowers the saw, as the drum winds it up or releases it and permits it to unwind. When the drum is released the weight of the saw frame unwinds it. The ridge at the center of the pulley is a convenient means of engaging it with the shifting fork.

A slot is cut in the upright guide sufficiently deep to permit the insertion of a one-inch lever, an end of which is pivoted to the main sill. This lever has

a few inches vertical play and crosses the path of the slide which carries the saw below and at right angles to it, but directly above a toggle joint. As the log is sawed and the slide descends it reaches and presses against the free end of this lever which, as it is forced down, finally depresses the toggle below it until the latter is pressed shut and its free end made to crowd the end of the shifting-fork lever to one side. This forces the cone into the drum which raises the frame of the saw by winding up the cable. As the frame rises its top bar presses a similar lever above it, which, at a given point, releases the toggle again and shifts the pulley from the drum. At the same time a similar toggle has been depressed by this second lever and the shifting fork made to engage the second drum, which advances the log. This second drum revolves until the log, pressing against the top, releases, by means of a rope, the second toggle and returns the shifting fork to an intermediate position. The second cut is then ready to be made without the operator so much as lifting his hand.

Theoretically, once a log is placed upon the slide, it may be entirely sawed up before requiring the slightest attention; in the meantime the operator could go to the woods for another log. In practice, while the rig may be made to work complete, it should never be left entirely to itself. All the regular operations of sawing up the entire log it can be made to do, entirely with engine power. But logs intended for wood are seldom straight or free from knots, and the little unexpected hitches and irregularities inseparable from such rough work as wood cutting require the supervision of the human brain. The man who runs the rig may devote practically all of his time to other work. He should be at hand

though, in case a projecting knot or bit of bark should happen to check the advance of the log, as otherwise the engine will most certainly try to force matters, possibly with disastrous results to engine or rig.

FIG. 129.—Wood Splitter Operated by Engine Power Works Well In Combination With Circular Saw.

503. **Wood Splitting.**—Even wood splitting is now done by machinery, some firms now having upon the market splitters that are guaranteed to split the knottiest oak or maple at the rate of 4 or 5 cords per day, with an engine of one or two horse-power. One of these and an automatic saw rig might be run by one operator at nearly full capacity.

CHAPTER XXIV.

ORCHARD AND GARDEN.

504. **Thorough Spraying Essential.**—There are some things which produce results in direct proportion to the thoroughness with which they are done, while others, unless the process is complete, are entirely unproductive. This is often true of spraying. In the lower branches of large trees the work may be ever so thoroughly done, but the lift to the upper limbs, particularly when a good many trees are sprayed, soon sets the muscles aching and relaxes our diligence. The result is a fine colony of some dreaded insect pest above the spray line to descend and undo the thorough work we have done lower down.

505. **Where the Engine Excels.**—A gasoline engine outfit puts greater pressure upon the escaping liquid and so divides it into finer particles. This obviates the danger of damaging the foliage by drops of over-strong liquid falling upon the leaves, as the fine spray, even though considerably more heavily charged with the poison, distributes it so evenly over the entire surface that a smaller quantity may be used and still be more effective. Then the fine spray, propelled by a greater force, penetrates crevices in the wood or nooks shielded by heavy foliage, which no reasonable amount of hand pumping would ever reach. The highest limbs, too, are as thoroughly sprayed as those nearer the ground, so there is no danger of some unsprayed limb, a little beyond our reach, furnishing

enough of the pests to undo most of the work that we have faithfully done.

506. Nature's Method.—One of the most efficient methods of spraying is to force the stream of fine mist high into the air above the tree and then let it float down by its own weight into the foliage. This is nature's method, and so long as she arranges the leaves for this very purpose we may be certain we can do no better than to imitate her method of applying liquid, which is always from above.

507. Real Purpose of Spraying.—Spraying, from being a desperate expedient, has become that last atom of human effort which renders all the rest effective, and without which, more often than not, the fruit grower's reward is a half-crop of imperfect and unmarketable fruit, or none at all. If a single tree is maintained at a loss it is one of those dangerous little canker-worms that devour the farm profits on so small a scale that it is not apparent, yet just as surely as though it were multiplied by hundreds and formed so large a part of the investment that to fail meant ruin.

Spraying is for protection; it is not a cure; and the man who does it incompletely either by not half penetrating the thick foliage or by missing the higher branches is like the one who weatherboards his barn and then leaves the roof frame uncovered. It is also an operation which has its own brief seasons. It is specially effective then, while it may be entirely useless at any other time. A day later may be compared to leaving off the shingles; a week's delay after the proper time may be like leaving off the whole roof.

508. Causes of Failure.—There are several reasons why spraying may fail of its object, of which the use of the gasoline engine will remove a number. Prob-

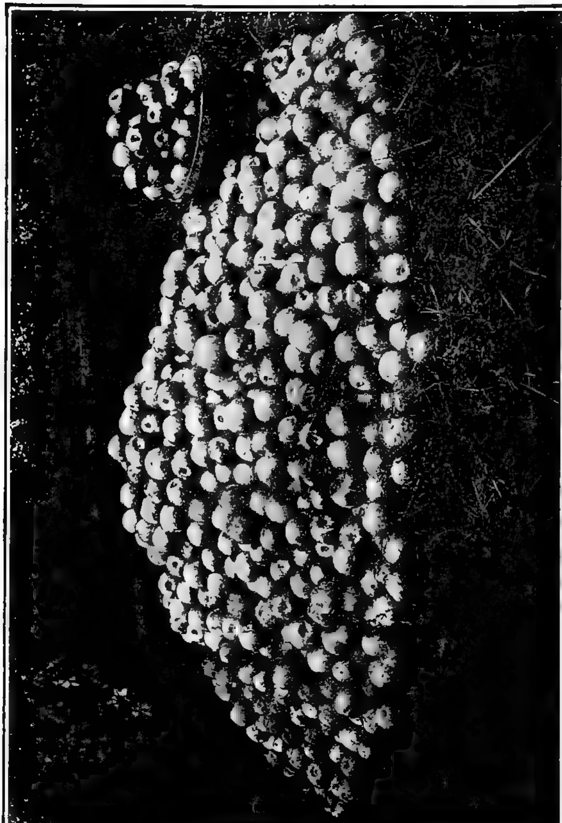

FIG. 130.—Fruit of Sprayed Trees. Sound Fruit In Pile, Wormy Fruit In Basket. On Adjacent Tree of Same Variety, which Was Not Sprayed, Only 42 Per Cent. of Fruit Was Sound.

ably no other farm process depends so vitally upon thorough work, because in the dealing with insect life that which escapes treatment on a single unsprayed limb may cover the whole tree with the pest that we are fighting so completely that all our thor-

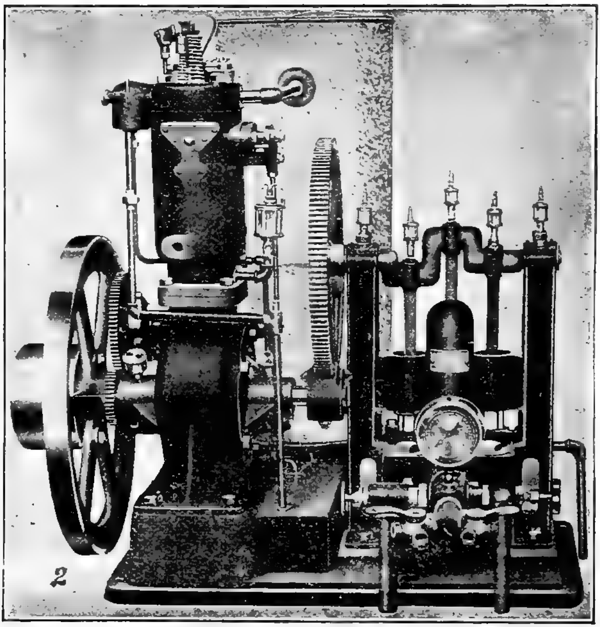

FIG. 131.—Gasoline Engine With Triplex Pump for Large Capacity Spraying Outfits or Water Supply Purposes.

ough work on the rest of the tree may be practically defeated. This does not mean that it is necessary to so drench the tree that all of its leaves are dripping with the poison liquid; indeed, the foliage may easily be injured by just this practice; and many an orchardist has taken to reducing the strength of his spray to

the point where it is only partially effective under the impression that he had been using it too strong, when, as a matter of fact, the trouble was in the over quantity with which he deluged the lower portions of the tree in his vain attempt to reach the higher limbs. For best results the spray should reach the entire foliage in a fine mist that moistens the whole of it, without drenching any part, and this is only possible where power is used and the liquid thrown with enough force to reach easily the most remote branches and penetrate readily into the densest foliage. Even the cracks and crevices in the bark must be reached in the case of many fruit pests—where the force obtained from hand pumping would never penetrate. One of the most efficient methods of spraying is to force the stream of fine mist high into the air above the tree and let it come down as a fog by its own weight into the foliage. This is Nature's own method of applying moisture, and the leaf growth has been arranged with the special object of doing this most thoroughly and economically, and it is very certain that we can do no better than to distribute it from above. This method, if backed by high pressure, insures a thorough and even distribution of the poison.

509. **A Successful Method.**—For the best results the pressure should not be less than from 125 to 150 pounds, while in practice the hand pump seldom rises above 50. The hose should be long enough to reach all sides of the tree with one setting and an agitator of the liquid in the tank should be provided. This is highly important; otherwise, the poison will settle to the bottom and the first of the liquid thrown will fail of efficiency because too weak while some of the settlings will be dangerously strong. Various forms of agitators for the smaller outfits are provided, but

they add something to the power required to work them and thereby become inefficient in hand-power outfits, either by being neglected or by rendering the work so much more tiring that it will be less thoroughly done. A gasoline engine never gets tired, and the extra strain of running a thoroughly efficient agitator constantly does not trouble it at all; so by its use the spray is properly mixed as well as applied.

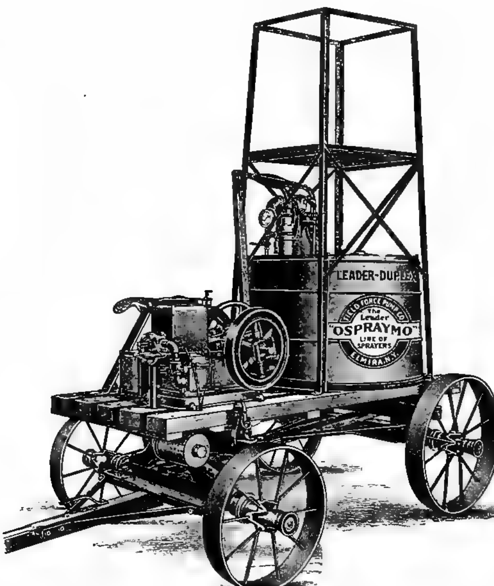

FIG. 132.—A Typical Animal Drawn Gas Engine Operated Spraying Outfit.

510. A Good Pumping Outfit.—A good spraying outfit may be made with a 1½ to 2 H. P. engine of either horizontal or upright design. Quite frequently the marine type is used and is as good as any if properly fastened to a foundation. Usually, though, the

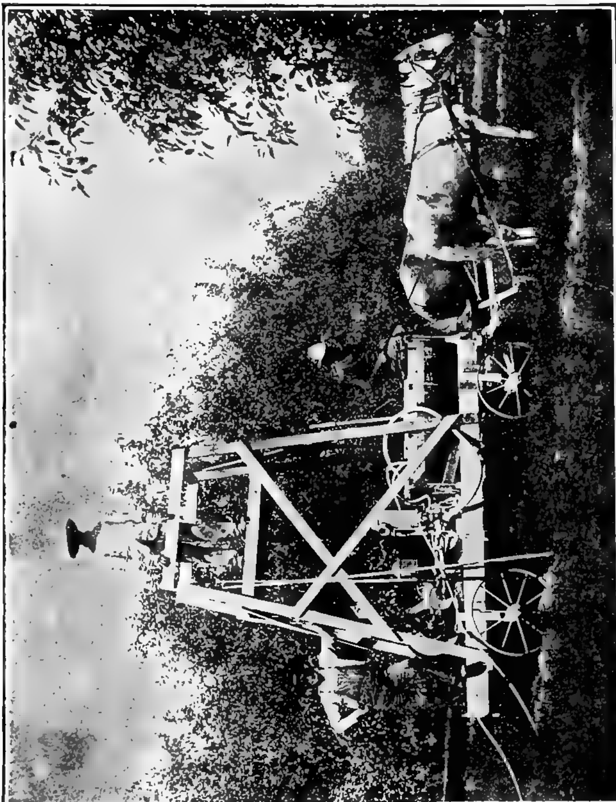

FIG. 133.—Portable Spraying Outfit at Work In Orchard, Show ing Utility of Platform In Reaching Top of Trees.

pump and engine mounted on a single base or directly connected are the most satisfactory as the two are then much easier held in a constant relation with each other, while with the two separately mounted the chance of one or the other shifting about and disturbing the power connection is greater, especially if the orchard, as often happens, is situated on a hillside or on broken ground.

The outfit should be so mounted that it may be easily turned and also may be readily conveyed under the low branches, although an elevated platform for the operator with an extension pipe is necessary where the trees are large. Of course the pump should be double acting; that is, water is taken in and thrown

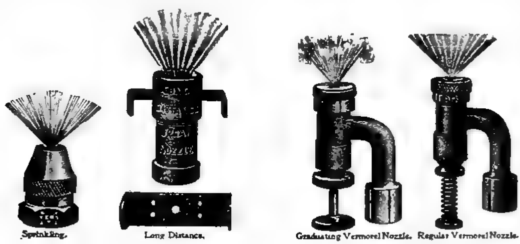

FIG. 134.—A Few Examples of Spraying Nozzles.

with both the up and the down stroke. It should be supplied with a relief valve for the return of a part of the liquid to the tank after the pressure gets too great. Of course no power outfit with which either gas or liquids are forced into an enclosed space can safely dispense with a pressure indicator; that is as indispensable as it is on a steam boiler, and should be as carefully watched for signs of failure.

511. **Good Nozzles.**—It would be the height of foolishness to provide an expensive spraying outfit and then fail in the work for want of good nozzles. Get

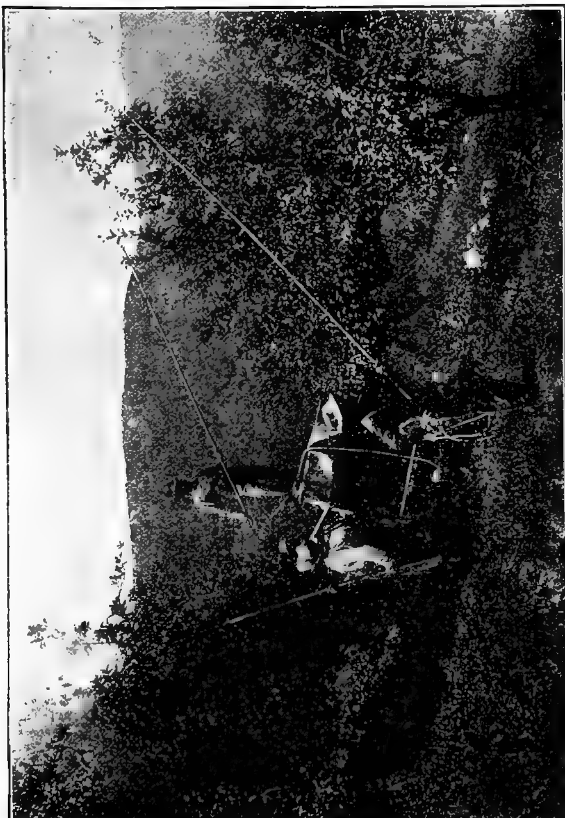

FIG. 135.—Power Spraying Outfit at Work.

the best, and do not be satisfied with one or even two. One that will work interchangeably with another, though of a somewhat different pattern and designed for another purpose, may be the means of saving the day if one of them suddenly plays out—and of saving the crop. One of the Vermorel types is the most popular. In this the stream is given a rotary motion as it leaves the orifice. For power spraying a grouping of nozzles is a great saving of time, two or more being so arranged that they are both used at once and vastly increase the area of the tree which is constantly being sprayed. A supply of coarser nozzles should also be at hand for use where the trees are to be thoroughly drenched, as in the case of using a lime-sulphur wash; also for spraying after the petals have fallen, as the greater direct force with which the liquid is expelled carries it more surely into even the most remote cavities of the calyx.

512. **The Hose.**—The best hose for power spraying is ⅜ inch, although the necessary couplings are not quite so easily obtained. One-half inch is perhaps in most common use and should not be less than 3 or 4 ply, with a pressure capacity of not less than 200 pounds per square inch. It is very necessary to provide for excess pressure. Twenty-five to 50 feet is a good length for working on the ground around the trees and 10 or 12 feet for use with extension rods. These are not only necessary for getting into the tops of tall trees but are convenient for working lower down because they carry the spray at any desired angle quite away from the operator. Often ½-inch gas pipe or less is used, though bamboo fitted with brass or other metal connections is lighter to handle and very well liked. One end of these pipes is fitted for direct coupling with the hose and should

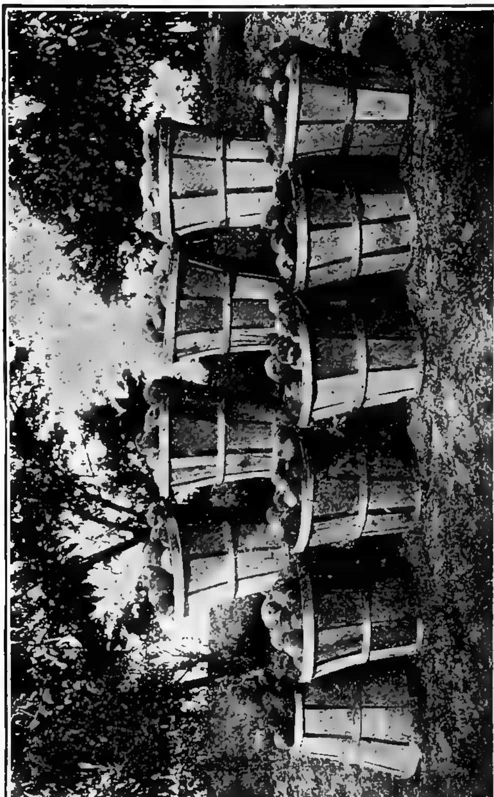

FIG. 136.—Results of Spraying Illustrated. Nine Baskets of Perfect Peaches, Unsound Fruit On Upturned Basket at Left.

be provided with a stop cock. At the other end the nozzle is attached. The pipes may be made in sections if desired for different heights of working, and may total anywhere from 8 feet to twice that height, depending upon the size of the trees. For high spraying a platform rigid and safe for the operator to stand on should be raised above the wagon bed 6 or 8 feet.

513. **Good and Cheap Outfits.**—All working parts of the pumps, the bar, the valves, etc., should be made of brass or bronze, as tin or iron is easily attacked by some of the liquids in common use. A good brass spray pump ought to be good for a number of seasons, and a good grade of hose for two or three, though some prefer to get a cheaper quality of the latter and then renew every year. This may be a little dangerous, because the hose that is cheap enough to throw away so quickly is apt to be so cheap that it is not of uniform quality. There is liable to be a weak spot in it—and an accident.

514. **Results of Spraying.**—The beneficial results of intelligent spraying are clearly shown at Fig. 136. A peach yield from sprayed trees consisting of a trifle over nine baskets is shown, and of these only about 2 per cent. of the fruit was unsound. As a general rule, spraying will result in saving over 90 per cent. of the fruit yield, providing proper solutions are used and applied in a careful manner.

515. **When Trees Are Not Sprayed.**—A low capacity spraying outfit is not desirable and a higher initial investment to procure first-class material is more than justified by the returns. When trees are not properly sprayed, it is seldom that 50 per cent. of the fruit yield is marketable if the parasites are at all active. If overlooked, the fruit grower will be exceptionally lucky if he saves 25 per cent. of the crop.

CHAPTER XXV.

IRRIGATION.

516. **Why Needed.**—"Irrigation is essential to all parts of the country where continuous and heavy cropping is expected. The farm which is always supplied with sufficient moisture will yield 20% to 50% more than another in the same region without a regular water supply. This has proved to be true in nearly all parts of the country, where averages have been kept for series of five years." The above statement, made by an agricultural expert in Washington, D. C., in effect sums up a number of good reasons in two words—better crops.

517. **Where.**—In the arid and semi-arid regions irrigation is, of course, a necessity. It has already reclaimed for cultivation tens of thousands of acres which were previously considered worthless and which would again become worthless if left to depend upon natural rainfall.

In regions of normal rainfall it is hardly less valuable because, although the full required amount of water may reach each acre of ground from natural sources during the year, much of the rain falls at a season when it does no good because it is not needed. Water applied by artificial means comes at the time when it does the most good because it is most needed, and considerably less water in amount may equal in efficiency or even surpass several times that which comes in torrents at irregular intervals.

518. **When.**—Everyone knows that crops are damaged and often ruined by continued drought. Not everyone stops to consider that even a short period of extreme thirst injures the vitality and quality of the plant as certainly as it does of a suffering animal. The quality of growing vegetables is greatly improved if plenty of moisture is always available to their roots through the entire growing season. To deprive them of this even for a short time is certain to give both the quantity and quality of the crop produced a decided setback.

519. **Where Drought Has No Terrors.**—Drought has no terrors for the man who has a really effi-

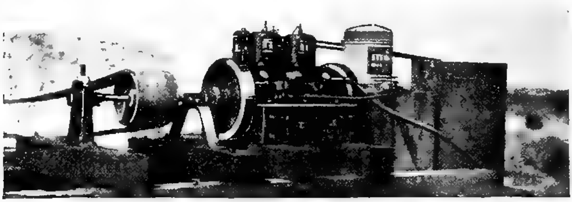

FIG. 137.—Drought Has No Terrors Where Power Driven Pumping Outfits Are Used.

cient irrigation system in a country where there is little rain; in fact, he finds it rather an advantage, as the rainfall does not then interrupt his work and he can at all times regulate the watering of his crops to his own convenience without subjecting them to excessive moisture or violent downpours. Many of the fungus germs, too, which are found in the air and carried into the ground or upon the plants by the rain, are avoided by the system of root irrigation, the water for which is pumped from deep wells.

520. **Certain Drawbacks.**—The expense and additional work of having to supply the water ourselves

are always the greatest objections to it. Then, when the supply is pumped from the rocks it is pure and does not carry the loads of silt always found to a greater or less extent in surface water and which, however objectionable it may be for drinking purposes, has a distinct fertilizing value to the growing plant. There are some other objections. These, too, are specially mentioned, because they are among the most important and because the gasoline engine has in a great measure done away with both.

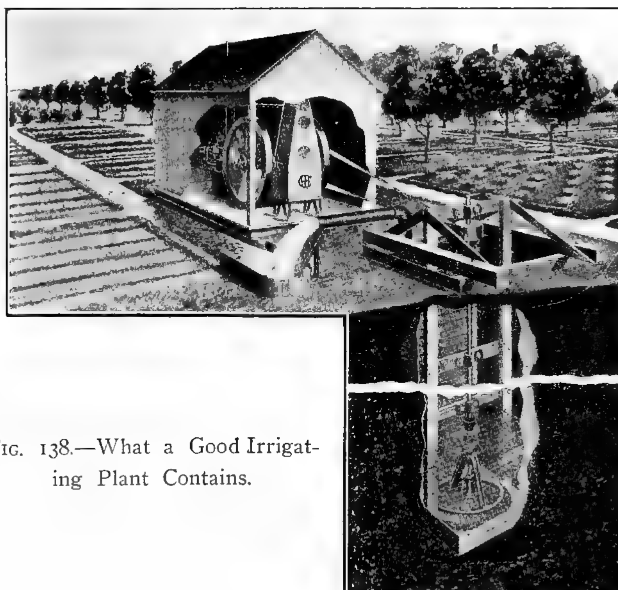

FIG. 138.—What a Good Irrigating Plant Contains.

521. **What a Good Irrigation Plant Contains.**—The chief essentials of a good water supply are: 1st, that it be economical; 2nd, reliable; 3rd, easily operated; and 4th, that it must not require too much at-

tention. Natural rainfall always fails in relation to the second and third essential and frequently, after pouring torrents have undone much of our careful work, seem to be deficient with regard to the last. The good irrigating plant must be economically operated, as the gasoline engine outfit is. It must be available whenever needed; must require very little attention and be so easily operated that one man can run the engine of a fair sized plant and have time to take care of the water after it is pumped. With a good gasoline engine he can do this, if the trenches are prepared in advance; can fill the oil cups, start the engine, and remain at work out in the field until the cups need refilling; four or five hours, if large enough cups are put on the engine. The cost of irrigating should be kept within $2.00 per acre for the season under ordinary conditions, and the supply can always be depended upon at the time and place it is desired. Root irrigation has the advantage that it can be applied at any convenient hour of the day, whether the sun is shining or not, while sprinkling from above is likely to do injury unless done after night or in cloudy weather.

522. Quantity of Water Required.—Corn, oats and wheat require from 350 to 400 tons of water per acre to bring them to maturity, but much of the water actually applied escapes, so that several times this amount must reach the ground in which they grow, if they are properly watered. One inch of water per acre weighs something like 112 tons and it is estimated that on an average it requires six acre inches to thoroughly irrigate the ground; that is, if none of the water soaked in or ran off, each acre would be covered with a sheet of water six inches deep. Two or three such irrigations as this per season will be

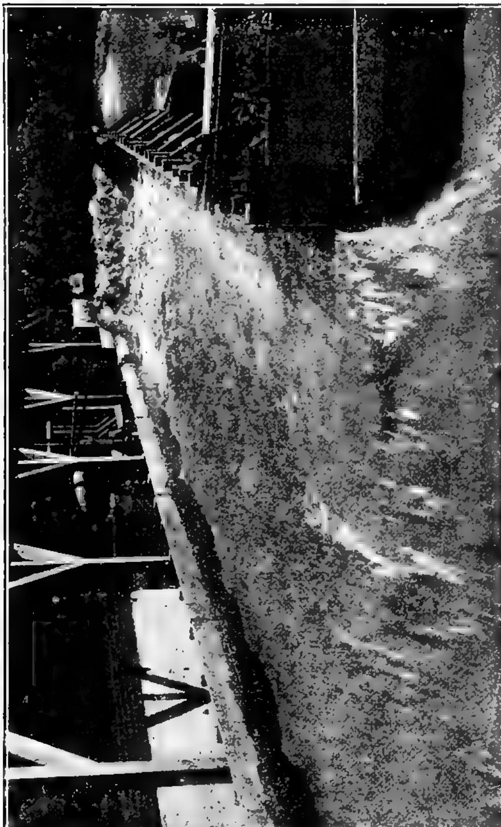

FIG. 139.—Plenty of Water Here.

needed, or a total of 16 to 18 inches. Making due allowance for the waste from evaporation, it requires a little less than 28,400 gallons to irrigate one acre of ground one inch deep, and an acre-foot requires about 325,900 gallons.

523. **The Cost.**—A general rule applied in many places is 5c. per acre for the season for each foot of lift. This requires a good engine and a good pump, neither of which will do the work without the other. It includes all operating expenses and supposes that the plant is in good working order and that the attendant knows his business. Bad management or unusual conditions may increase this cost a little and there are ways in which it can often be reduced. For instance, if there is a natural basin at hand or if one can be made by erecting a dam and holding back some of the natural waters that fall in too great quantity or at times when they are not needed, the amount of water to be pumped from a deep well might be decreased by drawing on the supply in the pond. For many reasons a good storage basin is quite a convenience.

524. **Engine Required.**—A good pumping plant once installed frees from all worry about moisture as no other system will; a poor one is itself a source of constant worry. Of course, the engine is the heart of the plant. Too small an engine means too low a speed for running a centrifugal pump most economically. On the other hand, too large an engine for the pump, unless so located that other work can be done with it at the same time, is not utilizing its own efficiency to the best advantage. The pump and the engine should be figured to balance each other very closely. A 10 to 15 H. P. engine will run a No. 4 to 6 centrifugal pump with a lift of 15 to 25 feet and

deliver around 2 cubic feet of water per second. A cubic foot of water per second equals about 450 gallons per minute and 600 gallons per minute will cover 1.3 acres one inch deep per hour, or 13.2 acres per working day of 10 hours. If the plant was run the whole 24 hours the amount covered would be 31.8 acres per day. Five and three-tenths acres per 24-hour day could be given the full six inches of water required for thorough irrigation and a plant of this size in continual operation might be able to supply the water requirements of a fifty-acre farm each ten days without rainfall if run continuously. A great deal, however, depends upon the lift required and the efficiency of the pump as well as on the crop and season. Under certain conditions an engine of this size has been found ample for irrigating 200 acres with a 20-foot lift.

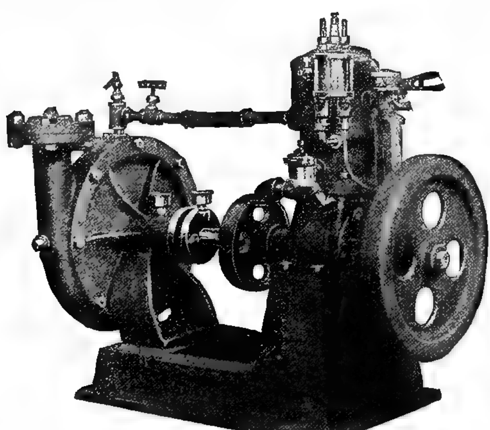

FIG. 140.—Centrifugal Pump Directly Coupled to Gasoline Motor.

525. The Centrifugal Pump.—For raising large quantities a short distance the centrifugal pump is

without a rival and is almost entirely used for purposes of irrigation and drainage. As they are valveless they are not likely to clog and are for that reason adapted to pumping muddy water which an ordinary valve pump would only handle under continuous protest, if at all, even such solid substances as

FIG. 141.—Small Gasoline Power Plant Operating Two Diaphragm Pumps.

large pebbles, walnuts, leaves, etc., not troubling the centrifugal pump seriously. The water also comes from them in a steady flow, instead of impulses as with valve pumps. Centrifugal pumps have been constructed that would deliver several hundred tons of water per minute.

526. **Their Limitations.**—Formerly it was believed that the centrifugal pump was only capable of lifting water a few feet and even to-day many people consider 40 to 50 feet the extreme limit of their working possibility. As a matter of fact, the single stage volute centrifugal has been operated on a lift up to 500 feet, but this requires so great a speed and such heavy power that a plant of this sort is too expensive for the irrigation of ordinary crops, the working parts of the pump being made of a special bronze and very carefully adjusted. Single stage pumps of this kind can be economically and safely used though up to a 100-foot lift and, by compounding the stages, this lift can be very much increased.

527. **Different Types.**—Centrifugal pumps may be of the vertical or horizontal form, the latter being sometimes called the top-lift and depending upon suction. They are placed at the mouth of the well and ought not to be more than 20 feet above the source of supply. As they are the easiest to install and repair they are in most common use. They often need priming, though, which the submerged does not. In some comparatively shallow wells, too, they would be useless because of the shifting of the water level, the water perhaps dropping 20 or 30 feet or even more after pumping begins before the level is reached at which it remains constant. In such a well a pump of this sort if set at the top would be beyond suction distance and if lowered to suction distance of the working level would be submerged when pumping was suspended.

The vertical type of pump will work submerged and may be lowered into wells of sufficient diameter, where, if properly installed, they do excellent work. They are specially intended for wells too deep for

the top lift pump and will be found most efficient if the suction lift is not greater than from 12 to 20 feet.

Centrifugal pumps are very sensitive to speed influences, their output being determined by the height of the raise and the speed at which they are run. A speed indicator should be used and, once the most efficient speed for a certain pump and well is determined, it should never be allowed to drop below that speed. It may for a short time go higher, but at a waste of energy and relative economy.

Centrifugal pumps are sometimes sold at a price too low for good internal finish. The blades and surfaces are left rough and without machining. They will work but, on account of the extra friction retarding the water, will be very greatly reduced in efficiency; in other words, by buying such a pump the continuous or operating cost is greatly increased in order that a few dollars may be saved in the installation cost. The purchase of cheap unfinished pumps is perhaps the most frequent and worst trouble against which the centrifugal pump has to contend. Their other chief troubles are poor priming, leaks in the suction connections, and being run at too low a speed, either because of wrong calculations or because the pulleys on both pump and engine are too small and too much power is wasted in belt slippage.

528. Garden and Small Farm Irrigation.—Where the lift is greater than 50 feet the subject of general irrigation as a regular dependence becomes somewhat questionable. For special crops, however, and as an occasional resort much greater lifts are entirely feasible; indeed, after a crop has been started and perhaps brought well toward maturity the most expensive irrigation one can imagine is that which might have insured a fine harvest, but did not, because it

was not done. It is very seldom that the rainfall is heavy enough at the right time to insure a full 100% crop without damaging it. Crops are every year reduced from 20% to 80% in some places by dry weather and thousands of dollars are annually wasted in the regions which do not depend upon irrigation, that might be saved by a little timely work in an amateur way. Even the difference between a good and

FIG. 142.—Garden Irrigation by Flowing Method.

a dried up garden may almost mean a living, during four or five months of the year at least, to the average farmer.

529. **For Deep Well Pumping.**—Driven or drilled wells, if deep or of small diameter, may be more advantageously pumped with some form of valve pump, although the cost, efficiency considered, is much greater. Power pumps for this are of two general classes, the horizontal and vertical. The first of these is for conditions not unlike those best adapted to the centrifugal pump, for shallow wells, cisterns, and springs.

The deep well power pumps sometimes require a long stroke and cylinder of small diameter. They consist of a rigid frame carrying the shaft for the engine pulley, upon which are keyed small pinions that mesh with large gear wheels near the rim of

which a crank-pin projects. To these are attached the connecting rods, working on each side of the pump frame and carrying at their other end the cross head, which travels upon or between vertical guides and at its center operates the plunger rod. This is the general type. Special features refer to discharge pipe arrangement, air chamber, valve location and distributing arrangements. These pumps are often run in connection with artesian well cylinders which may be lowered any depth into the well and operated near its bottom as suction pumps below and lift pumps above the plunger. Connection is made between the

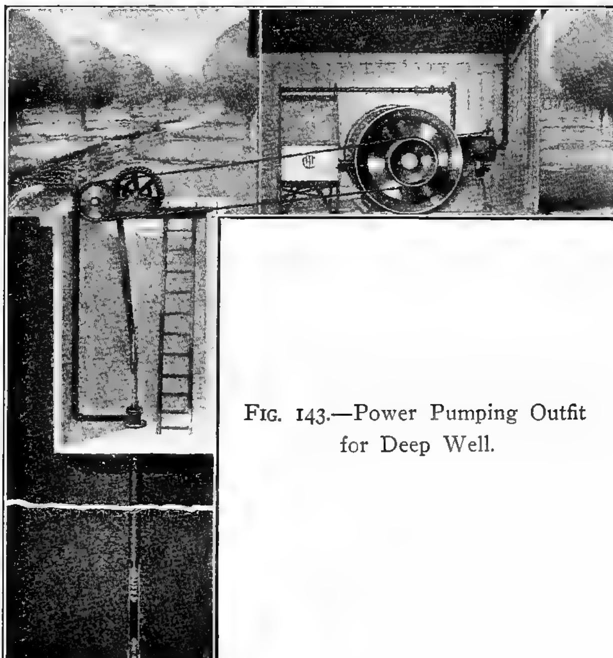

FIG. 143.—Power Pumping Outfit for Deep Well.

plunger and the crosshead by means of wooden rods, coupled together to the required length. Air chambers are used at the distributing tees where the water is forced any distance from the mouth of the well or into elevated or pneumatic tanks. For the latter, they may be so arranged that the air will be compressed for use in the tank by the action of the pump itself to the

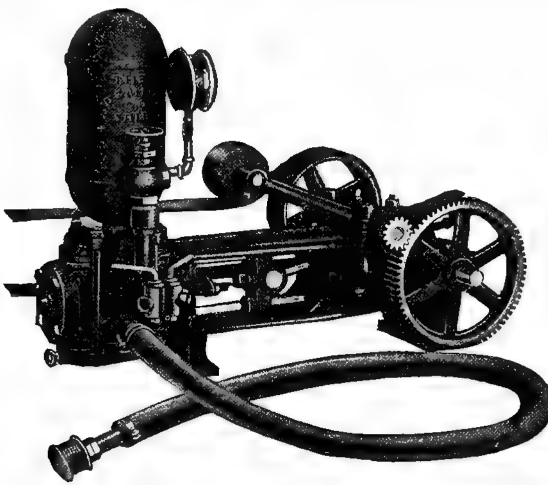

FIG. 144.—Deming Horizontal Power Pump.

desired amount and then cut out at will, without interfering with the working of the pump.

The horizontal pump is also intended for forcing water into tanks and may be equipped with the same air condenser. The pulley shaft is generally carried on the cylinder head; connecting rods working from each end of this along each side of the pump body to a guided crosshead which works the piston in the cylinder. This avoids all twisting thrust and not only reduces strain but also friction. Valve chambers at

some convenient point contain the suction and discharge valves. Access for cleaning and repairing the valves is usually through hand holes for that purpose, so the cylinder head need not be disturbed. A good pump of this type is provided with tight and loose pulleys and should be operated at a speed of about 40

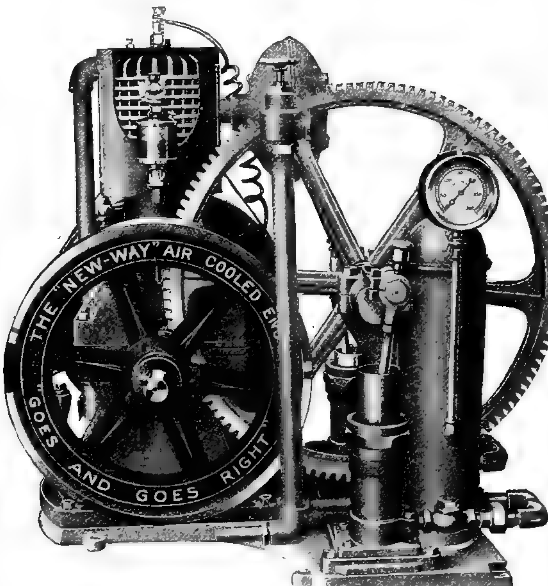

FIG. 145.—Air Cooled Engine and Pump Mounted on Common Base.

strokes per minute. These belted power pumps, though long known, as now developed are a direct result of the gasoline engine.

530. Distributing the Water.—Instead of the irrigation ditches and expensive provisions necessary in the west for extended irrigating, the truck patch and family garden may be watered without great outlay.

Usually it is best to first pump the water, or a portion of it, into a tank of moderate elevation. It is rather more convenient to distribute from a tank than direct from the pump and water pumped from a great depth is apt to be too cold. By standing exposed to the sun the temperature is more suitable. With a garden hose, a spray nozzle and a moderate pressure the water may be applied from above. This is necessary in the case of grass and similar close-growing plants, but for garden crops and plants in rows root

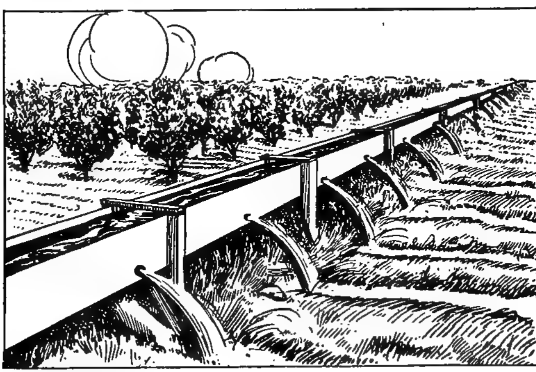

FIG. 146.—Water Distribution by Seepage Method.

irrigation is the best. This is done by running the water into small trenches on each side of the row of growing plants. The trench made by a cultivator with shovels set for hilling up is just the thing, particularly if the garden is cultivated with a wheel hoe and the rows close together; say a foot apart. Run the hoe exactly as though hilling up, being careful not to cut through the headlands at the ends; then across the highest end of the garden cut a similar furrow somewhat larger than the others, by expanding the

wings of the hoe a little and deepening by several cuttings. Connect the tank or the pump with this main ditch and then see that it is opened to each of the irrigating trenches cut between the rows. The discharge pipe from the tank should end in a horizontal wooden box with holes in the side or one end removed, to avoid the wash that would accompany the continued discharge of water under pressure upon loose dirt.

The trenches should all be prepared before the water

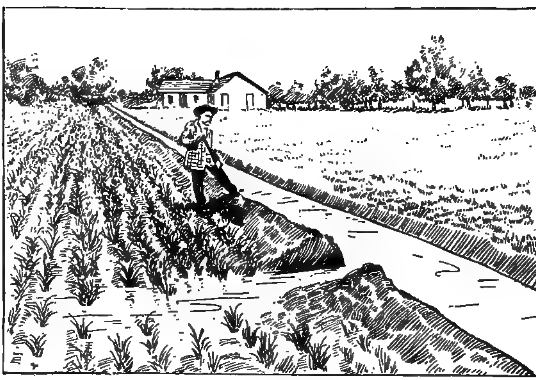

FIG. 147.—Water Distribution by Flooding Method.

is turned on. Then oil up and start the engine, connect with the tank, open the escape from the tank into the head ditch and the rest of the job, aside from an occasional supervision, may be turned over to the engine. Without interfering with the regular field work, it is possible to start up the engine just before supper, after the night chores are done, and then just before bedtime go out and shut down the engine, the work completed and a fine crop of vegetables or berries saved. In time of a severe drought it is not much

of a farm garden that will not produce more than a small gasoline engine costs in return for occasional treatment of this kind.

531. **Kinks and Cautions.**—Where the spraying method of watering is used do not apply the water until after sunset or else before sunrise or on a cloudy day; never when the sun is shining.

If a full stream of water fails to come from the pump and the supply in the well is ample try running a little faster. If that does not work and the pump seems to be in good condition it is probable that the strainer is deficient in waterway.

It pays to keep the connections between tank and pump tight and free from leakage. The greatest troubles and expenses come from neglected minor details. This is specially true in relation to the engine itself.

Trouble always means expense. To cut expenses down keep things in order.

A breakdown in dry weather may mean ruin to the crop and loss of all work previously put upon it.

Other things being nearly equal, select that implement, machine or system that is likely to give the least trouble afterwards.

Produce from a well watered garden will be fresh and marketable in spite of drought.

CHAPTER XXVI.

THE WOMAN'S STORY.

532. **What Machinery Has Done for Some Farm Women.**—From perpetual motion to hours of reasonable industrial requirements the daily working period of the modern farmer has been reduced by farm machinery. In some instances the wife has shared in this emancipation; in a good many others the only direct benefit she has received from the mechanical helps she has helped to pay for is a partial or complete escape from having to go out in the field and help the men with their work after having done her own. Men no longer care to cradle and rake and bind their grain by hand. Still less would they favor a hand-power threshing machine or fodder shredder. They sometimes forget that a washerful of clothes requires some form of motive power even if the washer itself is of the latest design. Nearly all washing machines are rated by machine men to require from a ½ to 1 H. P. engine and the average man is expected to be capable of producing 1/7 H. P. How about the woman who has to turn the washer by hand? The average wringer turns even harder than the washing machine, and the clothes all have to go through it three or four times. Is it any wonder if the woman who turns it sometimes thinks longingly of that willing little helper, the gasoline engine, that would do the hard part of her washings for her if it had a chance?

533. The Farm Power Laundry.—No doubt the average woman would be so much relieved by having the washer and wringer turned for her that she would be satisfied for weeks to come; still it is much more economical to install complete plants, once the power is supplied, than to provide a few separate

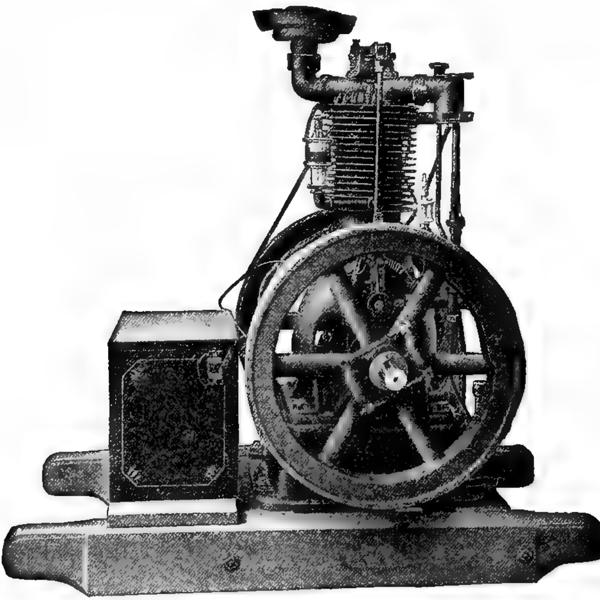

FIG. 148.—The Woman's Engine.

items. It will cost some money but the beginning is the most expensive part of it.

The complete power laundry should include a washing machine and wringer mounted together and arranged to operate at the same time or either one alone, at the will of the operator. There should be space on the tub rack for one or two rinsing tubs, beside the washer and the wringer, made to slide along

a frame to operate over any of these and in either direction. The clothes may then be wrung from any one tub to the next one without lifting. The wringers on some power washers are thrown in and out of gear by a foot pedal; on others with a lever. It is very important that, whichever method is used, the device should be within easy reaching distance of the operator at any time so that the accidental catching of the clothing or a finger between the revolving rub-

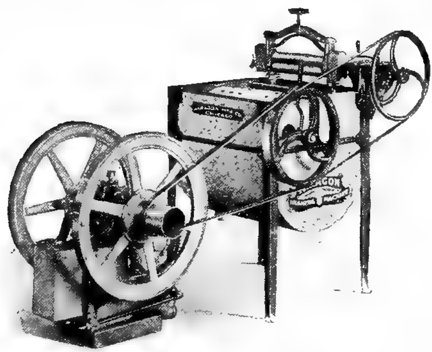

FIG. 149.—The New Washerwoman Lightens a Former Household Burden.

ber rolls may be checked before any serious damage is done. Unprotected gear wheels about a washer should never be tolerated, the clothing is so easily caught and wound in. A belt drive is much safer, though belts are rather prone to slip when run near soapy water. Some washers have enclosed gear which is comparatively safe.

Washers are on the market which are guaranteed to handle the heaviest carpets or the most delicate lace curtains. This claim should be made good to a reasonable degree. There must be no bearings where

the oil required will reach the clothes. In many of the modern washers raising the lid of the machine throws it out of gear and stops it until the lid is again closed. This is much more convenient than having to shift a belt or stop the engine whenever it is necessary to turn or examine the clothes. A reversible drip-board makes it possible to wring the clothes from one rinse tub to another; then back again into a new

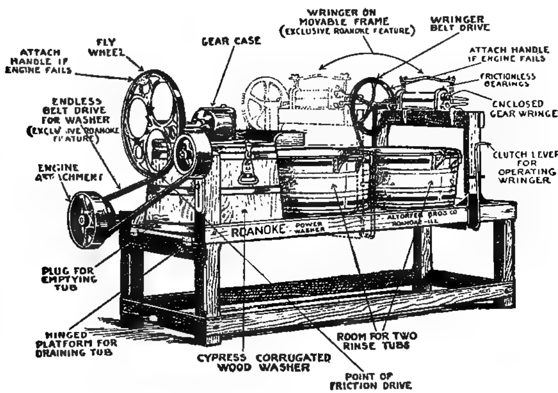

FIG. 150.—A Complete Washing Outfit Adapted for Use With Power.

water; or, one washing may be going forward at the same time that an earlier one is being rinsed.

The best washing machine in the world is not complete unless conveniently placed faucets supply hot or cold water at will to any of the tubs. This may be arranged by a swinging faucet for each over the central tub but with the swinging arm long enough to reach over the other tub or the washing machine as turned. For convenience the arms may be kept folded back against the wall when not in use. Both tubs and washer are drained from below by means of faucets

emptying into a sink or basin from which the water is conducted by a pipe. From the time the clothes are put into the washer until they are finished ready for the drying line they need never be lifted excepting as the ends are inserted between the rollers of the

FIG. 151.—No Lifting Excepting to Fold for Wringer.

wringer and the pieces straightened out as they are being run through. If effectively arranged, a good sized family washing can be done in from ½ hour to 1 hour with very little drudgery for the operator. The engine does all that, and does not mind it in the least, but the power washing outfit is no longer merely a

concession to aching back and muscles; it is an economic necessity in the household as surely as the

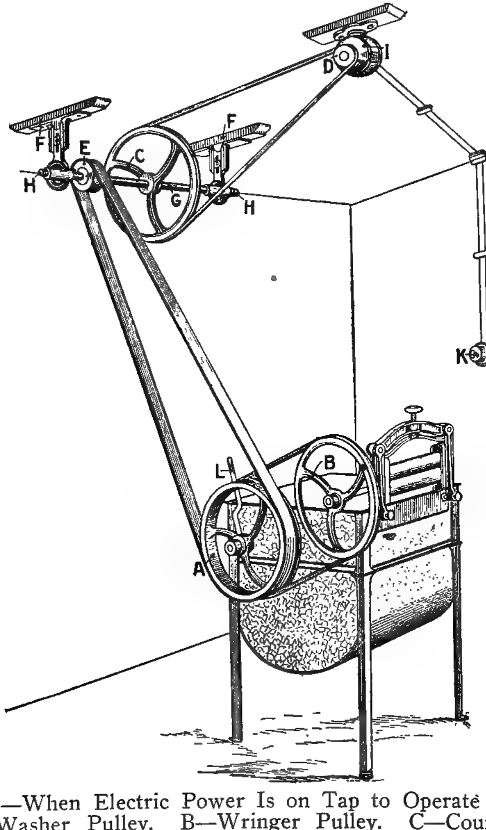

FIG. 152.—When Electric Power Is on Tap to Operate Washer. A—Washer Pulley. B—Wringer Pulley. C—Countershaft Pulley. D—Electric Motor Pulley. E—Washer Driving Pulley on Countershaft. F—Hangers. I—Electric Motor. K—Snap Switch. L—Power Release Lever.

binder is in the harvest field, while the price of two 5c. cigars a week for a few years is enough to pay for the outfit.

534. **Ironing by Engine Power.**—This may be done by means of the mangle, engine run. The smooth rolls of polished steel, operating much like a wringer, are usually heated by gas, where that is available, and take the place of the hot flat-iron admirably, the operator merely having to fold and arrange the garments. As the pressure between the rolls may be regulated at will, not even the most liberal expenditure of "elbow grease" can be as effective as this nerveless laundress that never tires and does not have to ease off on the pressure because of aching arms. Where gas is not obtainable some other means of heating the air in the interior of the rolls, which are hollow, can be obtained.

535. **The Water System.**—A good old proverb states that water never rises higher than its source. The success of any laundry is limited to its convenient supply of water, but the same engine that supplies the power is specially adapted to supplying the water also. Not even a special kind of pump is necessary, though sometimes it is preferred. There are pump jacks on sale that may be hitched to any hand pump, and in such a manner that the pump may be released and used in the ordinary way in an instant.

536. **The Storage System.**—With a gasoline engine there is no necessity for storing up enough water at a time to last until the next wind blows; the power is always available. For some purposes, though, water under pressure is a distinct advantage, even though it is no more work to start an engine up than to pump half a pail of water.

537. **Elevated Tanks.**—An elevated tank outside is at the mercy of the hot sun in summer and of freezing troubles in the winter. If set indoors, there is apt to be more or less drip and leakage to rot out the

timbers of the house and cause dampness, with always the possibility of a weakened hoop, a burst tank and disaster.

538. **The Pressure Tank.**—The water storage system under present favor is the pressure tank, which consists of an iron or steel cylinder holding anywhere from a few to many barrels, and tapped for the inlet pipe from the pump and the discharge for the distribution of the water. A third hole, small in size, is usually made for attaching a pressure gage or indicator; or this may be made a branch of the other

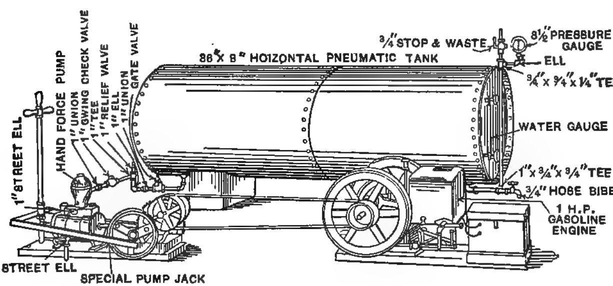

FIG. 153.—A Complete Pneumatic Water Supply System Gives Important City Convenience in Country Homes.

pipe but must not under any consideration be omitted, and is far more dependable when attached to its own orifice.

The tank, of course, is full of air at first and the air condenses as water is forced in by the pump until it forms an elastic cushion in the top of the tank with a pressure sufficient to drive the water, out through the distributing pipe, to any part of the house. Usually the pumping is continued until the pressure gage shows 30 pounds. As the air in the tank would not alone supply enough pressure to force nearly all of the water out, more air is pumped in so that when the

gage shows 30 pounds pressure there may not be enough water to more than half fill the space. Many power pumps are now made so that air or water or both together may be forced in by the engine. Of course, a much higher pressure may be carried by forcing in more air.

539. **Advantages Over Elevated Tanks.**—There are several advantages which a pressure tank has over one that is elevated. In place of being set in an exposed position, if outside, it is usually buried under ground; if in the house, it is in a cellar or basement where any accident would flood only the one room instead of the whole house. Because of the location of the tank the water is cooler, and because of the air forced through it it is thoroughly aerated and much more palatable and wholesome.

540. **Making Use of It.**—With a pressure or elevated tank installed and a convenient means of filling it, the water system of the farm house is merely a question of distribution, and may be made quite as complete as that of any city house. Hot and cold water can be had with the turning of a faucet in any room desired, upstairs or down. The modern bathroom, for years so impossible for the farmer to possess, is one of the most natural consequences of the tank. With water coming to the faucets above the tubs the laundry becomes a complete plant, and of course the same method will be used to bring water into the kitchen sink. By running up a little extra pressure at cleaning time and attaching a hose, both upper and lower windows may be washed thoroughly without removing the sash or risking a broken neck. One of the beauties of this system, an advantage over that in the city home, is the control the individual has of the pressure. On special occasions it may be run up to the

point which would under ordinary circumstances be unnecessary and inconvenient. In the country home, too, the water may be pure; there is no excuse for its being otherwise, but the city man has to drink whatever is furnished him and must pay for its production under the management of somebody else.

Mopping, one of the dreaded tasks of the farm housewife, becomes, with the pressure tank, a matter of very little concern. A few turns of the engine will drive the pressure to the point where the hose will easily take the place of the scrub brush. There need be no more wringing out of dirty rags with bare hands, and no corners are too inaccessible for the hose to reach without any stooping or hard work.

541. **Dish-washing.**—In the same way, but with a smaller pipe and less pressure, much of the dish-washing can be done without wetting the hands. The dishes placed in the sink and soaped as needed, hot or cold water, or a combination of the two, may be turned upon them with sufficient force to do the washing more effectually than any hand work and in less than half the time. Dishes not injured by heat may be washed in water much hotter than the hand will bear; then the pressure under which it is applied is even more of an advantage.

Mechanical dish-washers now on the market are quite a little in use in hotels, and are frequently run by engine power. They are a convenience. Without them, though, but with this easily regulated pressure at command, the housewife on the farm has quite as efficient a dish-washer as the city housewife and one that will not be nearly as destructive to the dishes as the average hired girl.

542. **Outside the House.**—Lawn sprinkling, while not eactly a part of woman's work, falls to her fre-

quently; that is, she assumes it rather than see it go undone. To the flower beds and pet shrubs she is accustomed to carry a good many pails of water in the course of a season, but the engine could do it for her through the pneumatic tank a great deal easier than she can and much quicker, for he makes no return trips empty handed. Automatic sprinklers, too, may be introduced; such details every one, once the means is at hand, will work out for themselves, and enjoy the fun of doing it. As a general thing there are some fruit trees near the farm house if there are any on the farm. If the women folks have an engine and pressure tank to carry water for them it will soon be noticed that the trees around the house are pretty certain to bear some fruit whether those in the orchard do or not. Everything that has life carries within it a large percentage of water, and a good many small boys and women folks have had reason to conclude that life itself was most of it made up of carrying water for the rest of creation.

543. **The Vacuum Cleaner.**—With provisions for convenient water cleaning it is time to consider that which is best done dry. Whenever a really new machine comes out one may judge a good deal as to its value by the number of cheap imitations which are thrown upon the market. The vacuum cleaner is one of those machines mentioned earlier in this book which does not reach its full efficiency until some more efficient power than is ordinarily available is applied. Hand power is not enough, though hundreds of hand-power machines are in daily use and are pronounced a success; still they lack in complete efficiency. It is the extra pound of energy which makes their success absolute. The gasoline engine can supply that.

544. **Cleaning House.**—House-cleaning time is

largely dreaded because of the general tearing up considered necessary. With the vacuum cleaner this is done away with, providing the cleaner has its full efficiency back of it. With the stronger machine and more complete vacuum available with engine power, the carpets may remain upon the floor and be thor-

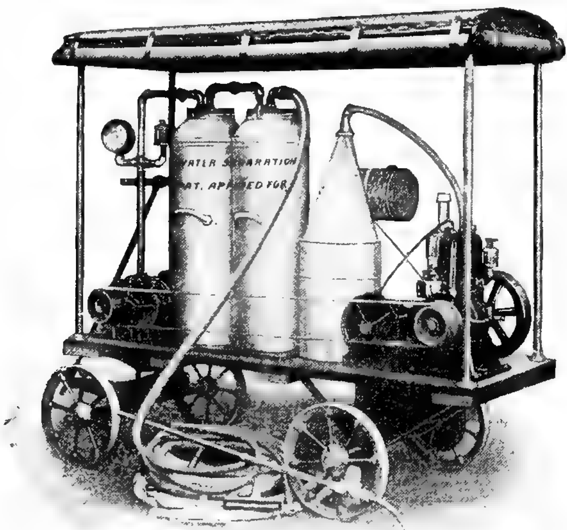

FIG. 154.—A Portable Vacuum Cleaner Operated by Cushman Farm Motor.

oughly cleaned every day instead of twice a year. Not even moths can resist the suction of a vacuum cleaner that is working as it should. With a clean carpet always, there is less dust to settle on the furniture, although the vacuum cleaner is supplied with a special nozzle for cleaning it. Window curtains and the most delicate draperies are cleaned where they hang. Even the wall paper may be brightened by this method of

renovation as well as by the comparative absence of dust. Clothing may be brushed out and cleaned after a muddy ride and the beauty of it all is that the dirt is really removed instead of being chased from place to place. When one stops to consider the work being done by these comparatively new assistants there seems to be some little foundation for the advertised claim of one establishment: "We clean everything but the baby and leave everything but the dirt."

At the barn more than one progressive dairyman is now currying the cows with a vacuum cleaner and in that way, just before milking, ridding their coats of all dust and loose hairs without loading the air with dust that will settle into the pails while the milking is being done. Power for this purpose is supplied by the same engine that runs the milking machine in the same stables.

545. **Milking Machines.**—While the milking machine seems at first thought to belong to the stable rather than the kitchen, it is a part, and an important one, of the dairy, over which the woman usually presides. Milking machines of the past have some of them been unsanitary, inefficient, expensive and positively harmful. Any mechanical device which is objectionable to the cow is sure to decrease the milk flow. The successful machine must be easily cleaned, sanitary, strong, time-saving, economical, and not injurious. It must also reduce the amount of help needed or else increase the possibilities of the help employed in number of cows handled.

The milking machine of to-day is not more difficult to clean than the average cream separator. Some special devices are needed with it; so are they with the separator. It is more sanitary than hand milking, as the work is all done under cover. The milk at no

time comes in contact with the dust or odors of the stables from the time it is drawn until it is poured into the separator tank. There is nothing about it that cannot be made strong; that is merely a matter of manufacturing economics. It milks a cow more quickly than a hand milker can, and one man can be milking two or even four cows at a time. It is economical in permitting a reduction in the number of

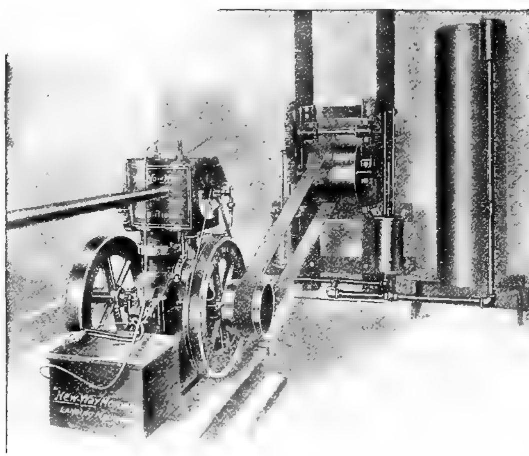

FIG. 155.—Creating the Vacuum for Milking by Gasoline Power.

men employed or of an increased number of cows that the present force can manage. That it is not injurious to the cows has been indicated from the fact that they no longer object to it, some of them standing more quietly than for hand milking and giving better results. It also frees the owner from absolute dependence upon hired help. Formerly he either had to keep a number of men or else reduce his herd to a point where it could not be run the most economically, and

if he chose the former course he was absolutely at the mercy of his men.

While several different machines are now in use a description of one will answer for all. The machine consists of a heavy covered tin pail with a cone-shaped top, the disc-like lid of which contains the vacuum motor operating on the cows. One rubber tube connects this with a pipe overhead from which the air is exhausted by the engine. When the stopcock is opened between pail and pipe the air in the pail is dis-

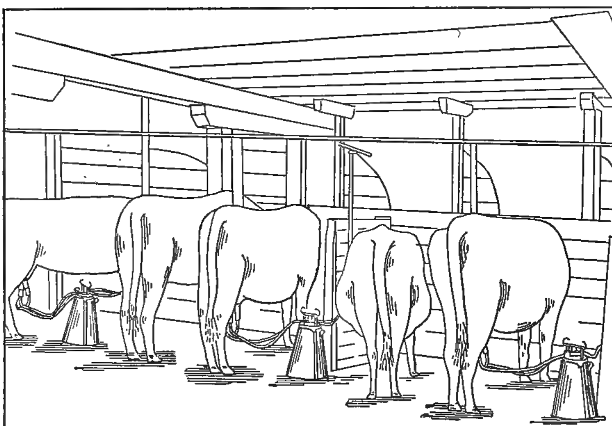

FIG. 156.—Milking Cows by Vacuum Process Cleanly, Sanitary and Not Injurious to Animals.

tributed through the vacuum and a suction set up. The pressure carried is about ½ an atmosphere or 7½ pounds per square inch. Valves prevent the milk from being drawn back into the pipe and give continued suction for 10 to 15 seconds, then pressure, about 60 pulsations per minute, is applied by alternating the suction with the pressure of an air compressor. One pail or machine is set between two cows. A vacuum

reservoir is connected with the pump to prevent too high a vacuum. Two rubber tubes, each with a glass section inserted for inspecting the flow, lead from the top of the can to the cows and terminate in four caps which are adjustable as to size. The operator should watch closely that all of these are working, and, as soon as milk ceases to flow through glass sections, should shut off the suction. One machine is usually allowed for every ten or twelve cows. While the machine should have intelligent attendance, there is nothing complicated about it, and trouble comes to it through misuse rather than from any fault of the machine. No doubt milking machines, like all other important inventions, will be greatly improved upon after they have come into more general use, but in their present stage they are neither less efficient nor more objectionable than many another farm utensil that is regarded as a success.

546. **The Cream Separator.**—It is possible to so contrive the stable arrangement that the milk, instead of falling into a pail, will be drawn along through a tube, from the milking machine, directly into the tank of the separator, which may itself be kept covered. At least one separator now on the market contains a gasoline motor in its own base and may be started up as soon as the milking begins and kept running continually until the work is done. This of course requires no intermediate pulley. As a rule, however, one of the special clutch or friction pulleys must come in between engine and separator, as the latter, though strong enough to do its own work, is not able to endure the constant though slight rise and fall of speed that accompany the impulses of the engine. Some separator bowls revolve as many as 20,000 times per minute, and are geared so high that a variation of 10

revolutions per minute in the engine's speed might make a difference of 500 to 1,000 in the bowl.

547. The Governor Pulley, Why Needed.—Separators do their work best at the speed they were made to run, and they must be protected against sudden

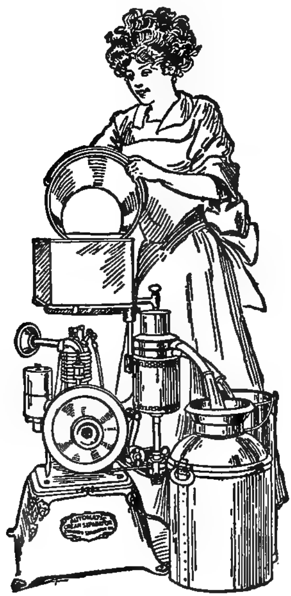

FIG. 157.—The Present Day Dairy Maid Uses Gasoline Power to Advantage. Note Engine on Base of Cream Separator.

jerks or extreme variations. Few people turn the separator as steadily as it should be turned by hand, and not many turn it fast enough. Without a pulley between there is always trouble when starting. A gasoline engine starts off at full speed; the separator has to be coaxed up gradually. This trouble can be overcome by means of a belt tightener, which can be thrown in easily and the speed of the spindle brought

up; after that it is at the mercy of the engine, no matter how unsteady the pull or how great the overspeed. This soon throws the bowl out of balance and ruins the separator. A steam engine can be run without any governor, and so can a power separator; neither one is safe nor economical. The speed of both should be right and it should be uniform. With a governor pulley and a gasoline engine the speed of the separator may be made both without any guess-work. The combination is better than hand work; not so much for a saving of work, as for conserving cream and butter fat.

548. **How It Works.**—The governor pulley is a friction pulley which controls the amount of energy

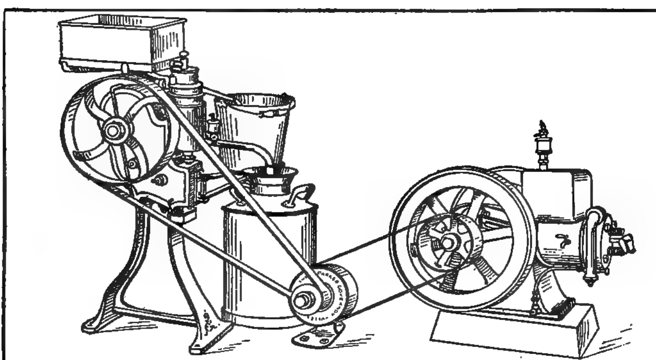

FIG. 158.—The Parker Speed Governor Pulley Secures Steady Separator Drive From Even Intermittent Gas Power.

or pull which the engine exerts upon the separator as the governor does the amount of energy turned into the steam engine. The central part of the pulley revolves with the engine and starts at full engine speed, with the shaft that turns it. As the wood friction blocks are forced out slowly against the rim of the

loose pulley that carries the separator belt, the latter is coaxed gradually into motion, the blocks slipping a good deal but holding enough to start the bowl. As the grip increases the speed of the bowl increases also, and the blocks slip less until they are finally brought into full contact and turn the belt pulley uniformly with the shaft. By means of weights and spring, however, if the speed of the pulley gets above a certain limit the grip is partially released, the blocks slip a

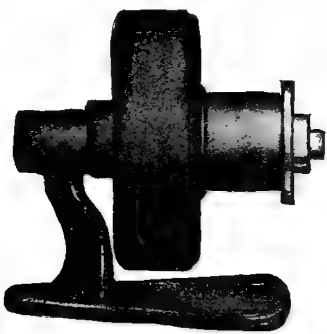

FIG. 159.—How Parker Speed Governor Pulley Is Employed.

little and continue to slip until the speed drops back to normal and the weights to their place.

549. For Bottled Milk.—Where milk is sold direct to families without separating, or where cream is sold, it should be aerated thoroughly. This may be done by allowing the discharge to run over a cone-shaped cap of tin which may, if cooling is also required, be packed with ice. The milk, discharged upon its apex, spreads out in a thin sheet and is cooled very rapidly. If cooling is not desired and aeration is the object, the cone may be made of fine strainer cloth.

550. Churning by Power.—With the coming of the gasoline engine butter-making is likely to again be

drawn away from the factory and revived upon the farm. After the cream is separated the work saved will be more than enough to run the cream into a revolving churn, throw on a belt and let the engine do the churning. The hard work in such a dairy is all done by engine power and under conditions that the operator can control. If the temperature is too low there is plenty of hot water to raise it; if too high, cold water will reduce it, and of course thermometers will be at hand to tell when it is right. Even the

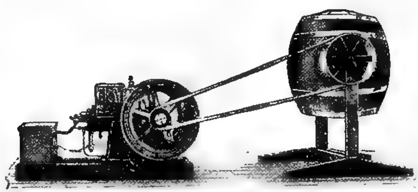

FIG. 160.—Churning by Power of Gray Motor.

butter working may most of it be done with power, several rotary workers being on the market that are easily adapted to engine action.

551. **The Ice Problem.**—Cold storage, or at least some means of applying a low temperature at will is an essential to good butter-making. Without it some people make good butter; their care and skill in every other detail overcome the lack in one, but their success is achieved in spite of the one lack and not because of it.

Ice-making is certainly not a woman's work, nor is ice-storing, but much of her work is made so much more effective with the use of ice that the subject is referred to hurriedly and its possibilities merely touched.

For the many farmers who wish to put up ice but dread to do so for fear of an accident if the work of

cutting is done with team power, a gasoline motor ice-cutting machine is illustrated; then, of course, whether the ice is to be stored at the edge of the pond or has to be hauled, the engine can be made use of just as readily as for any other kind of hauling.

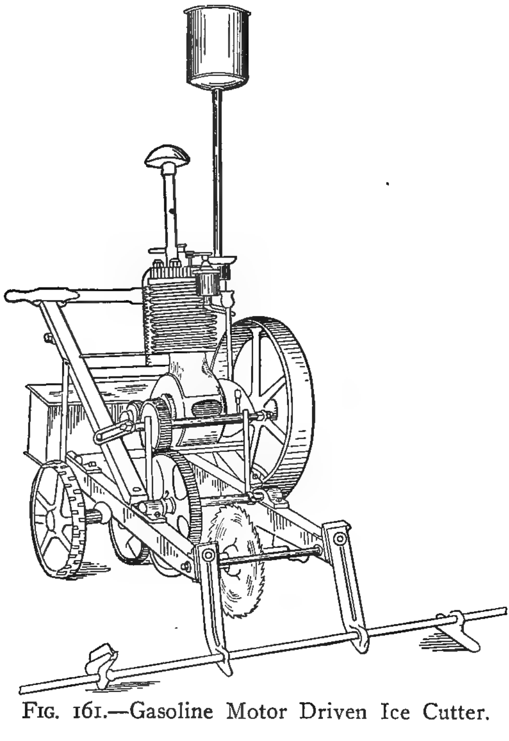

FIG. 161.—Gasoline Motor Driven Ice Cutter.

When the ice crop fails, or in parts of the country where there is no ice, artificial refrigeration has to be resorted to. Condensers, and in fact the entire plant, can now be purchased for family use with a capacity of as little as ¾ ton, the rating in this case meaning not the amount of ice manufactured, but the amount

of freezing or cooling capacity equal to that which ¾ ton of ice would have in 24 hours while melting. One of these small machines will cool for one day a properly insulated cold storage room of 80 cubic feet, or say 10x10x8. By a system of piping in connection with tanks of calcium chloride solution the desired temperature, once obtained, may be held for some hours and the engine used for other purposes. The same plant would actually manufacture about half of the above amount of ice in twenty-four hours. Machines of large capacity may, of course, be obtained. While outfits of this kind are somewhat costly, once installed, they may be operated on less than the annual loss sustained on many farms for want of ice; while a good team lost in some lake while harvesting ice would go far toward paying for an artificial plant.

552. **Other Household Uses.**—The ice cream freezer naturally comes to mind, after mentioning ice, as one of the uses to which gasoline engine power is daily being applied, though it may not be an important labor-saver in that one instance. It is the application of power to the countless little things, the doing of many things at once, the doing of **all** things more thoroughly than would be possible if it depended upon muscle power, that accounts for the extra time and vitality and satisfaction the housewife feels who really learns to make the engine help her in every task that comes to her, whether she ever heard of its being so employed before or not. Even if it proves to be no saving the first time, if it succeeds it probably will be the next, for she will know better how to go about it.

553. **A Handy Device.**—Back of each farm kitchen work-table a shaft two or three feet long and faced with leather should be stationed, with a driving pulley at the end, where least in the way. This may be

driven from a line shaft at the ceiling of the kitchen or from one hung under the floor. The entire leather face of this revolving shaft is virtually a friction pulley. Near it fasten in a row, by means of wooden buttons or easily adjusted clamps, some of the various revolving utensils of the kitchen, the coffee mill, the spice mill, the meat chopper, egg beater, nutmeg grater, whatever runs by wheel power. It looks like

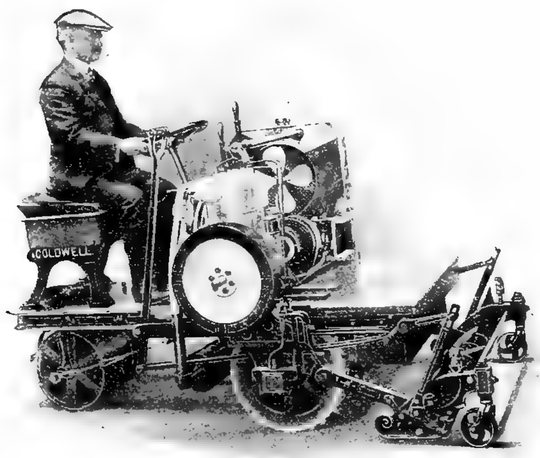

FIG. 162.—A Well Kept Lawn Insured With Motor Propelled Lawn Mower.

a foolish thing to use an engine for beating an egg. How about dropping the egg in to be prepared for that cake; then, by swinging the beater into place and turning a button so that its wheel is brought into contact with the friction shaft, being able to turn the attention at once to grinding the coffee for dinner. That in the mill, and the mill swung into line, we might just throw a nutmeg into the grater in prepara-

tion for the noontime pie. Or perhaps a batch of pepper is to be ground, or scraps of cold meat; maybe all of these. By the time they are all in place the egg is ready for use, enough coffee ground for the next meal or two; in fact a lot of odds and ends that would have kept one pair of hands busily occupied for an hour or more will have been gotten out of the way in five minutes without even a moment's tiring of the wrist, or the slighting of anything for want of time. Patent bread mixers are in extensive use by bakers

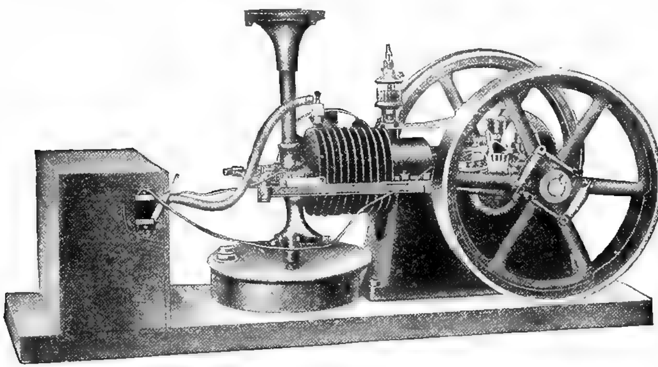

FIG. 163.—A Light Horizontal Air Cooled I. H. C. Engine Suitable for Household Use.

and in hotels, and many of them are run with engine power. If there is no bread to mix or if there is, set the engine to chopping cabbage or, if there happens to be fresh pork or beef at hand, just run out a mess of sausage; then if the engine is still running light, stop sweating, switch on that fan overhead and enjoy better air and a cooler kitchen. There are a lot of things in any kitchen that alone do not require engine power, that deserve it if enough of them can be collected together and all done up at once.

554. Cleaning Various Utensils.—When it comes to washing the kitchen utensils water pressure and rotary brushes, if necessary, will do wonders. Even the heavier dairy machinery may be in part at least cleansed as a direct result of engine energy. Of course the old rag that formerly was used in washing out the churn has long ago given way to a brush that may not be any more effective but is less offensive to the health inspector; still it has its germs. Maybe sprays of hot water under pressure have theirs, but they don't

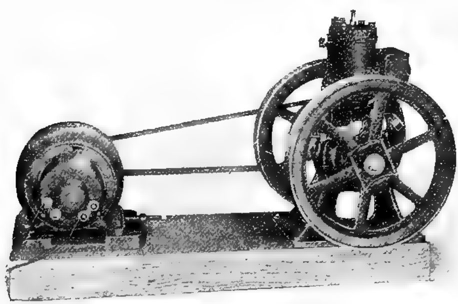

FIG. 164.—Dynamo Operated by Small Gas Engine Provides Inexhaustible Lighting Current.

live long. Cream separators have to be taken apart in order to be thoroughly washed, but as each piece is taken out it can be laid upon a frame where pressure water of any desired temperature is playing upon it. By the time the last piece is out the first and probably all of the rest have been well cleaned. Maybe the engine is not doing all of this work, but it supplies the energy that went into it.

555. Starting and Stopping the Engine.—Turning the sewing machine is fun for an engine, and the tread can be replaced with a foot lever for throwing a belt-tightener on and off in order to stop and start at will.

About every important task about the house the engine will take a hand at except perhaps filling the lamps and making the beds. Even in this it is not wholly useless. If an elevator is put in it will readily carry the bed-maker up to the task and then, if desired, down cellar, when the work is all done, to turn off the power. Even this is unnecessary work. A string can be carried from the end of the switch lever to the kitchen table and a pull upon it is enough to put out the vital spark and turn this jolly little helper in a moment into a piece of motionless iron. It will take a trip to the basement to revive the spark, but, by storing up a little compressed air in a tank for the purpose, or by a friction brake, we may easily ride down in the elevator and then, having started the engine, come up on gasoline power.

Such are some of the possibilities, serious and otherwise, of the gasoline engine as a helper for womankind. Many of them are given only suggestively. Actual conditions vary too much for accurate details. The fact remains that ingenuity and a little money may introduce into any department of housework, almost, a force that will save both time and vital energy for other lines of work. Filling the lamps we have not made the engine do yet. Let us see if that is possible.

556. **Filling the Lamps.**—A number of engines now on the market run so smoothly that it is possible to run a dynamo directly from the engine, but it is not always convenient to keep the power in operation at night, when lighting is needed; so a storage battery is by far the best, as a successful lighting system must be available at any hour. These batteries may be charged during the day, whenever the engine is running some other machine which does not require all

of its energy. At first, to save installation cost the battery may be small in size; enough for a little reserve electric energy but still depending in the main upon the engine itself. This is quite economical if the engine is no larger than necessary to run the dynamo alone. If larger than that all of its superfluous energy, without the storage battery, is likely to be wasted. The storage system can be added to, cell by cell, much like the sections of a built-up book case, until not only enough energy to run the lights for the entire farm for a night is stored ahead, but enough for some of the small tasks that might be done by the engine direct, such as running the sewing-machine. For many of these light tasks electric motors are even more convenient than the gasoline engine; still it is all gasoline power in another form, since it was the gasoline engine that created our electric current.

557. **Storage Battery Capacity.**—Storage batteries are rated in ampere hours, a 24-ampere hour battery meaning one that will give 24 hours of current service when not discharged at more than normal rate. A battery of this capacity may give 3 amperes for 8 hours at the normal rate, but if discharged at more than its normal hourly rate the time of its service would be more than proportionately decreased, so that its full 24-ampere hour capacity would not be reached. It is on this account important that the battery installed has sufficient capacity for all demands upon it. It takes about 10 hours to fully recharge at the same rate the 2-hour battery. A 36-ampere hour battery will run 9 15-watt 12-candle power tungsten lamps 7½ hours (the standard time of normal rating) in a 30-volt low voltage plant, which is satisfactory for the average residence lighting; it will run twice that number (18) only 2¾ hours, or considerably less than half

as long. On 110 volts (used generally in large lighting plants) it will operate 19 25-watt, 20-candle power tungsten or 10 50-watt 16-candle power carbon lamps 7½ hours.

As there is always some wasted electric energy in the use of a storage battery it is more economical to operate the lights in part from the dynamo and depend upon the battery rather as an assistant when it is not convenient to run the engine. Still, the storage bat-

FIG. 165.—Electric Farm Lighting Outfit Turns Night Into Day and Provides Another City Convenience for the Farmer.

tery does prove that a gasoline engine can be made to fill ready for lighting the finest lamps in the world.

558. **Lighting Up.**—For the man or woman in the living rooms above lighting up consists only of pressing a button or, more often, of turning a thumb-screw in the base of the lamp. The duty of the attendant in the basement is hardly more difficult, though of a different nature. At one side of a well equipped electric light outfit stands the switch-board (see Fig. 166). If

the lamps are to be operated from the dynamo only the dynamo or main switch is closed by bringing the handle downward until the copper frame is pressed into the grooves made to receive it. If the battery is to be charged, the two battery switches are raised. If the lamps are to be run with the battery only, the dynamo switch is opened by raising the handle and bringing the two battery switches downward.

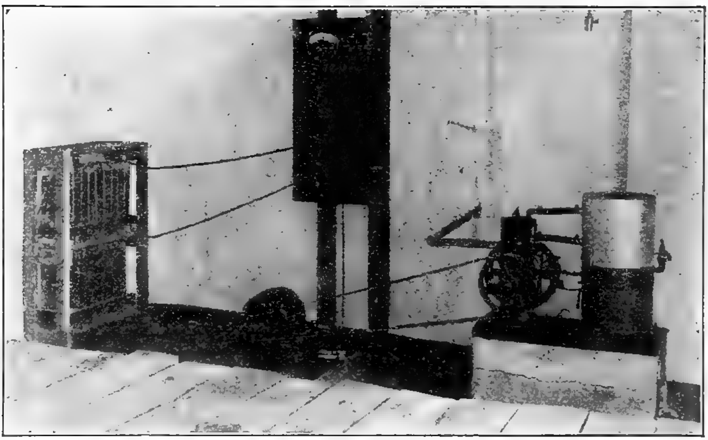

FIG. 166.—Complete Residence Lighting Outfit for Country Use.

559. The Complete System.—The conditions placed upon an engine used to run a dynamo are so severe that it was long considered impossible to meet them with a power which, like the gasoline engine, acquires its energy in bunches; in fact, the present high efficiency of our best steam engines was forced upon the engineering world to meet these electrical demands. To belt a dynamo directly to a gasoline engine is to reproduce in the current sent out all the energy pulsa-

tions of the engine. Lights run directly from the dynamo would flicker and wink. This may be in part overcome by putting heavier balance wheels on the engine and so absorbing in their heavy rims slight speed variations. Governor pulleys are also sometimes used, the same as for a cream separator; or the current may be conducted to a storage battery and then drawn from that. Several engines are now on the market, however, that run so steadily that

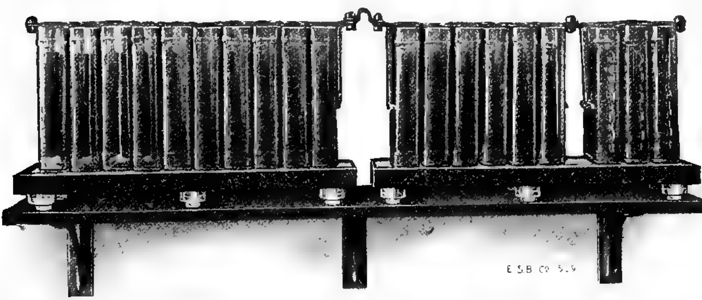

FIG. 167.—Storage Battery Employed In Connection With House Lighting Outfit.

quite satisfactory results may be obtained from the direct belted dynamo providing the engine is not overloaded.

The low voltage (30-volt) outfits generally favored for residence and farm lighting consist of about a 2 H. P. gasoline or kerosene engine, say a 50-light dynamo, a storage battery, switchboard, and the lamps required for the place, with necessary wiring supplies. If there is plenty of room the dynamo should be driven by a belt; if not, it may be direct connected with the engine, but a belt driven outfit is rather more steady.

An outfit of this sort will furnish plenty of light for the average residence, barn and out-buildings, and at the same time the dynamo is charging the storage battery the engine may be used for other light power such as cooling fans, cream separators or any light running device that develops little speed variation; or a part of the current produced may be directed into convenient little electric motors for running sewing machines, ice cream freezers, or into elec-

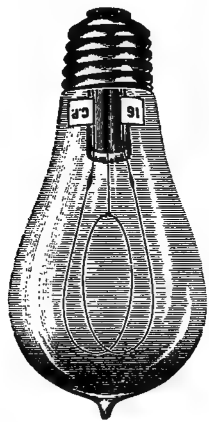

FIG. 168.—Electric Lamp Using Incandescent Filament.

tric flatirons and many other household conveniences. Where much of this work is to be done a larger dynamo and engine will be necessary. If general power engines are used for electric light work they must be of the highest grade.

The wiring system should be as short as possible as there is always more or less waste along the line, usually 5% or more. The lighting plant is not complete, though, that fails to include the barn in the circuit. Not only is the electric light much more

convenient than any other kind, it is much more effective and safer. There is no chance for overturned lanterns and the lights do not blow out at just the critical moment. When caring for sick stock the electric light is of special value. These low voltage plants are not in the least dangerous as they are not powerful enough to be harmful if by accident an uninsulated wire was touched.

560. **Door Maid and Burglar Chaser.**—Among the earlier household conveniences likely to be installed after the electric light has been established is a system of electric door-bells and electric burglar alarms. The latter is particularly valuable in the country, where, as a rule, the attention of marauders is given to the hen-roost or horse stable or some part of the premises so far away that the invasion could not possibly be heard at the house, except by accident. Not only will these electric signals frighten intruders away but they will keep them away more effectually than any watch-dog can. Either bells or buzzers or, perhaps better still, an electric light can be so wired in, that the opening of a door at night will close an electric circuit and flood the place with light.

561. **Making Electrical Conveniences Available on the Farm.**—Practically all of the household duties that the gasoline engine can do the electric motor can do even more conveniently, after the engine has given it the power to do at all. Without the engine electricity could not be made available on more than one farm in a hundred, and even where electric power plants are within wiring distance the man who must depend for his power upon someone else, rather than upon his own resources, is at the mercy not only of every breakdown but of all the strikes and disputes between labor and capital without having any voice

whatever in their settlement. At best, the average price of electric energy when purchased is more than its production costs upon the farm and it is only into the home-grown product that the farmer may put his own work or that of his eager boys. Taking the country over, the average price charged by the central station companies is 12 to 15 cents per 1,000 watts, which is equivalent to about 1⅓ horse-power. Making a fair allowance for losses in transmission, the cost of the home-made current is less than half of that produced in the distant plant.

562. **The Engine the Housewife Needs.**—The gasoline engine for the woman must not be hard to start. Some of the first light engines brought out were too heavy and difficult; the average woman became disgusted or discouraged. The man who has been accustomed to pottering with machinery problems all his life may be willing to spend two hours making an engine do a bit of work that he could do without it in twenty minutes, rather than give up. The average woman will do the work the old way and order the engine to the junk-pile.

The household engine must be moderately clean in its habits. A woman may put up with a tobacco-soaked man, but with an oil-soaked floor and greasy engine—never.

It must not be immoderately noisy, and it must be dependable. After she has used it enough to form a lasting attachment for it she will overlook some of its occasional short-comings. At the first, the chances are she does not more than half believe in it anyway, and every little fault will only add to her suspicions.

In short, the engine that a woman wants is one that

will relieve her of a portion of her worries instead of adding to them.

563. **The Farm Girl and Boy.**—Someone has discovered that the way to keep the boy on the farm is to keep the girl there, and there is a good deal of wisdom in his discovery; still it is only a half truth. The rest of it is to make farming conditions and country life such that it will develop rather than suppress the best social and intellectual tendencies and respect the courtesies of life. Both the boy and the girl prefer the drudgery of some phase of city life which is a complete mystery to them to that of the ditch-digger and scrub-woman some of them are familiar with in their own neighborhoods. Such conditions have been abolished in many parts of the country and wherever this is so we will find farm conveniences and farm machinery in an advanced state of development; the development, in fact, being largely responsible for the conditions. No boy or girl of independent spirit can willingly become a part of a life that seems inferior and humiliating so long as the world seems to offer better opportunities elsewhere. It isn't so much the lightening of their work that they demand; it is the elevation of farm life from the drudgery of the slums to a plane of which they have no need to be ashamed. It means the touch of beauty and cultivated taste that all right lives desire; an occasional hour of leisure for self culture, for improvement, for recreation, and that, too, in the midst of surroundings which suggest something more than constant hard work. The average farm boy is not lazy and neither is the farm girl. They do not wish to escape work so much as to reap some of the rewards for it that they have earned, one of which is the right to develop their best ideals with-

out the depressing influence of humiliating comparisons. If there are any means within the reach of to-day's farm life for permitting this, that cheerful little plodder, the gasoline farm engine, is the most important.

564. The Price.—Reckoned in dollars and cents, the price of all this saving of a woman's energy may run anywhere from $20 up; less than the cost of a binder, a mower, a corn harvester, a hay rake, a drill, a loader or any one of a dozen other man-saving devices. At least one special household engine, guaranteed to develop a full 1/4 horse-power and capable of running almost any one of the devices suggested at a time, can be purchased in one style for $16 and in another for $18; then there is the additional cost of installation and applying, in money, work and ingenuity. The price of one good cigar a day for a month, of one doctor's bill, of a few weeks' loss of time while recovering from the result of overwork, of a few months' washing bill if done outside, of the waste in cream and butter fat that occurs between factory and farm; any of these, if we count it up in dollars and cents, would represent the price.

565. What Others Pay.—The price that others pay, that we pay, if we persist in the old methods, is not to be so easily computed in coin of the realm, though it has a liberal expression in that also. The real cost, however, is in human life; in the life of the housewife that is shortened by overwork; that is blighted even before it is completed by the ceaseless, hopeless, unending drudgery which is never lightened by a sense of completion or by a promise of anything better for to-morrow than the unending treadmill of to-day. The real cost is the home influence

out of which the entire family is cheated because there is no time for anything but work; not the work that uplifts and inspires but the sort that dulls the intellect and kills out the ideals which are a legitimate part of human life and of which no one, young or old, has any right to be deprived. The real cost is the lost respect of the young people for the farm, which is to them a synonym of resultless toil; their hatred of all that pertains to farm life, almost of domestic life, because of its caricature which has been forced upon them by a system of hard work which has all too often been allowed to degenerate into the drudgery that makes of the home only a place to eat and sleep—and work.

CHAPTER XXVII.

HOME-MADE CONVENIENCES.

566. Self Moving Engines.—With the possible exception of wind-mills, home-made tractors have undoubtedly been launched in greater variety than any

FIG. 169.—Tractor Sawing Outfit of Leslie Reed, Cottonwood, Idaho, Goes to Work Under Its Own Power and Is an Ingenious Home Made Apparatus.

other form of home contrivance of importance on the farm. This has partly been due to the general call of the farm for power and partly to the tardiness of

the manufacturers in seeing either the possibilities along this line in the farm gasoline engine or the peculiar requirements which a farm tractor must fulfill. Tractors and trailers had become so much a fixity in the manufacturing brain that no one but the farmer himself thought of considering any other design.

567. **Light Power Tractors.**—Naturally the first attempts at farm tractor building were of the simplest kind. A pair of discarded mowing machine wheels furnished the drivers, to one of which a belt pulley was securely bolted. The other was left to turn free, and so the necessities of differential gear were avoided. A belt run from the engine to the drive wheel pulley applied the power to the work. A tightener pulley applied and released by a lever made it possible to start the engine without moving the drivers and then to turn the power upon them gradually. A team was sometimes hitched ahead to do the guiding or a guide rod similar to a regular tractor might be rigged. Any form of vertical drum upon which is wound at its center a length of rope which terminates at each end at the front axle makes a complete and cheap guiding outfit. Such a tractor can be made at very small cost, less than $10 outside of what material may be pulled from any junk pile, and it makes a very convenient means of moving an otherwise stationary engine about from place to place, under its own power. Many 3 H. P. engines have been utilized in this way, while even as small as 1 H. P. tractors have been reported. This latter outfit had a speed of 6 miles per hour, would climb any ordinary hill and was capable of carrying two people besides moving itself. Its rear wheels came from an old mower and the front ones from a worn-

out go-cart. Instead of the drum guide it was furnished with a lever which connected at one end of the front axle with both a rope and an iron rod. When the lever was pulled the rope drew the axle back; when it was pushed the rod shoved it ahead. As extreme lightness has to be sought in these very small power rigs in order to keep within the capacity of the engine, there can be little tractive power and the work can only be of a carrying nature, the load being applied to the axle of the drivers from above and so adding to their tractive capacity. On a draw-bar pull so light a rig could not be very effective.

568. **The Horseless Buggy.**—Quite naturally when it was discovered that small engines could actually be made to propel themselves, somebody thought to load one into a buggy and connect up in a similar way. The wheels of course lacked width and tractor lugs; still the greater diameter made the experiment enough of a success to warrant other attempts and it is not uncommon to see these home-made horseless buggies travelling around at a fair speed in sections where the roads are not too hilly. Where tractor lugs are found necessary, a makeshift that has the merit of cheapness may be made out of heavy fence wire wound spirally about the tires and properly secured.

One rather unique road outfit was constructed out of a 2 H. P. marine engine mounted on ordinary bicycle wheels with the cones taken out and babbitted to a steel shaft. It was driven with chain and sprocket and developed a speed of about 15 miles per hour.

569. **Low Power Trucking.**—Greater working capacity can be gotten out of these small engines on trucking outfits than in any other way, because all the weight of the load put upon them, within the

capacity of the engine, adds to their tractive power. Motor trucks which carry the engine within themselves have a very much higher percentage of efficiency than do tractors used to exert their energy at the drawbar, and this advantage is, of course, more marked in the smaller engines than in large ones that have more or less power to spare. Farmers who have taken advantage of this fact have frequently obtained surprising results from their small-power engines and have in effect moved themselves several miles nearer to their city markets than they were while depending upon horses.

570. **What an Old Farm Wagon Can Do.**—The ordinary farm wagon, harnessed to a gasoline engine in the simplest manner, can be made to do almost the work of the factory truck so long as the pull is always straight ahead and at the same rate of travel. In practical work, however, it becomes necessary to introduce differential gearing and so permit of short turns and all inequalities of rate at which the driving wheels revolve. It is not good economy to apply the power to one wheel only when hauling loads and not convenient to apply it separately to each of the two wheels. The differential is the only really correct solution. It is also often necessary, when going over difficult ground, to slow down much below the rate at which the wagon should ordinarily move, nor is any working rig satisfactory if it cannot be backed a few feet or inches by the same power that propels it. For these requirements a transmission, including gear shifts of some sort, is essential. All add a little to the work of construction; also to the expense, but they add still more to efficiency, which after all is the true measure of profitable construction. With this in mind a number of farmers have constructed motor

trucks of their own with which they can go any place on the farm at a safe rate, and on the road at a speed that makes them far more profitable than a team, although they did not cost as much. With 3 to 6 H. P. engines farm wagons have been turned by home work into motor trucks capable of hauling the full capacity of the wagon at a load and of making at least three trips to market while the average farm team makes one.

571. **A Rapid Post-hole Digger.**—Making the hole and setting a post complete for the wires at the rate of one a minute would be considered quite a feat by any fence-builder, but the gasoline engine with a home-made rig can easily discount that. If there is a hoist at hand that can be mounted on the sills of the engine the work is greatly simplified, it being only necessary to add to the rig a couple of uprights 12 or 15 feet high, well braced and boxed to guide a descending weight between them, and fitted at the top with an axle bearing a crown or sheave pulley for carrying the rope. An iron weight weighing from fifty to one hundred pounds is secured to one end of the rope which passes over the sheave to the drum of the hoist and works easily up and down in the guides. By throwing the clutch to engage the drum this weight is wound up and lifted; then hand power or an automatic clutch-release frees the drum and permits the weight to fall several feet upon the end of the post, which should be suspended over the spot where it is to be driven, so that it may of itself take a vertical position. The post, of course, is sharpened same as for hand driving, but a few blows delivered by such a force will settle it into the earth much quicker and more securely than the most vigorous of hand driving. A stop should be provided under the

weight to prevent its descent below a certain point; then all the posts driven will be left the same distance above ground without the trouble of measuring. The truck on which the outfit rides may be hauled by team or by one horse, though it is much more convenient to make it self propelling, as the engine has nothing else to do while being moved from post to post. The weight should be large enough in diameter to permit of some variation in locating the post, as the rig may not always be stopped exactly on the line of the fence.

Where a ready made hoist is not at hand the same results may be obtained by substituting for it a home-made drum or wheel of large diameter in the rim of which a crank-pin catches and then suddenly releases the rope, exactly as is done by the drill in well drilling. With a well made outfit of this sort one can drive posts almost as rapidly as they can be swung into place, a very few blows from such a weight being enough to sink a post any reasonable depth.

572. **The Home-made Well-drill.**—Home-made well-drilling rigs are practically only simplified extensions of the post driving outfit. The uprights must be high enough to lift the drill and auger stem clear of the ground and strong enough to support it. Auger stems for water wells usually run from 6 to 25 feet in length and weigh from 150 pounds up, a three-inch stem weighing about 23.5 pounds per foot of length. Where a very short string of tools is used the length of a joint of pipe or tubing will determine the height of derrick as it is much easier to add to the height than to cut and thread each joint.

After strength and capacity for handling standard length pipe, the main features that determine the success of a well-drilling outfit are the lift of the tools and the suddenness of their release, their power to

penetrate the earth depending upon the number of foot-pounds energy per minute with which they strike. It is evident that a weight of 300 pounds falling a distance of two feet will deliver twice the force in foot pounds of that given by a 150-pound weight falling the same distance; also that its penetrating capacity would be doubled if its fall was four feet instead of two. Whether this force were delivered in the form of a sudden blow or as a gradual thrust matters only because, if the latter, it indicates that there is either an excess of friction against which the energy of the descending mass expends itself or else that a part of the force is absorbed by the rope. If it is the latter, it means that the cable is being restrained so that the foot-pound energy is being expended in part upon that instead of on the rock; that is, the release of the cable is not quick enough or complete enough to allow the falling tools to follow the call of gravity without interference. The drilling speed depends entirely upon the hardness of the material penetrated and the number of foot-pound energy delivered against the rock.

573. **A Good Barn Hoist.**—Two stout brackets or standards, preferably of iron, support each end of a stout iron shaft on which revolves a flanged iron drum to which, when used in hoisting hay, the hay rope is attached. A friction clutch or disk which revolves with the shaft is pressed forward by means of a lever against the drum and made to revolve it as rapidly as the shaft revolves or less so, as the contact pressure is increased or diminished between the disk and drum. The pressure may be maintained by holding the lever on, in case the operator wishes to also run the fork at the load, by means of a small rope attached to the lever, while a heavy spring con-

stantly tends to draw it back and insures the drum stopping promptly when lever is released. By easing the friction contact the load may be held at any desired point or lowered a little and then caught and held. With a return weight attached to hay car, when the load is dumped and the clutch released, the drum revolves as a loose spool upon the shaft and unwinds

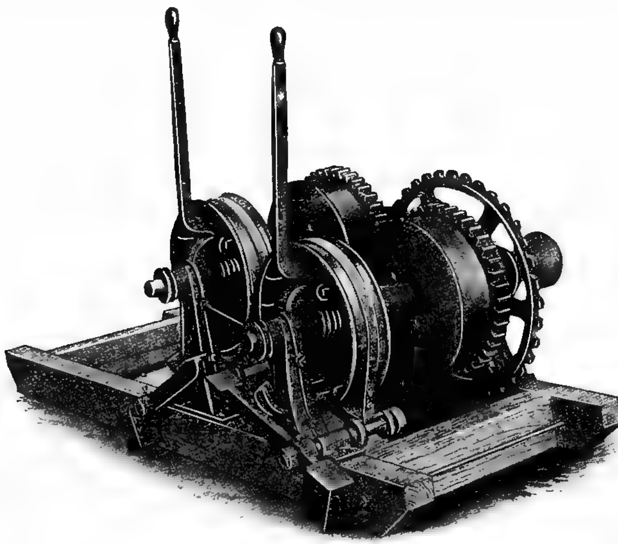

FIG. 170.—Double Drum Hoist for Use In Connection With Gasoline Engine Made by Brown Clutch Company.

the rope readily, with far less pull than is necessary in drawing a heavy rope back over the ground. The shaft itself is geared or belted directly to the engine and revolves in the one direction constantly. In lifts of this sort gear or sprocket wheels are preferable to belts on account of the slippage of the latter under intermittent pulls. It is of great importance that the

shaft be heavy enough to insure against bending or springing. A good three-horse engine ought to operate a well made rig of this sort with entire satisfaction and will unload hay considerably more than twice as quickly as a team will, especially if there is a shortage of help. One man on the load can tend fork and hoist very nicely, leaving all the rest of the help free to go into the mow if they are needed there.

The same rig can, of course, be used for swinging up hay ladders, hoisting wagon-boxes or elevating loads of any kind. By means of it a small elevator may be operated from beside the threshing floor and the grain taken in lots of ten or more bushels to elevated bins, though a more convenient arrangement for the purpose is the regular grain elevator.

574. **Grain Tender at Threshing Time.**—Elevated grain bins have many advantages, the most important of which, perhaps, is the ease with which gravity may then be made use of when bringing the grain to the stables, the feed mill, fanning mill, or when loading it for market. As a rule, too, elevated bins may be located in some out-of-the-way place where there is room to spare instead of on the main floor where perhaps every inch of space is needed. The one drawback to them is the work required in getting the grain into them. This work the gasoline engine is always ready to do.

A first class grain elevator is worthy of a permanent location; it should be made a part of the barn itself. Having determined about what the position of the separator grain spout will be at threshing time, take up a couple of planks from the threshing floor and build a hopper-shaped bin or one with sloping bottom in between the joists; one that will hold from five to ten bushels of grain. Cut off enough from the

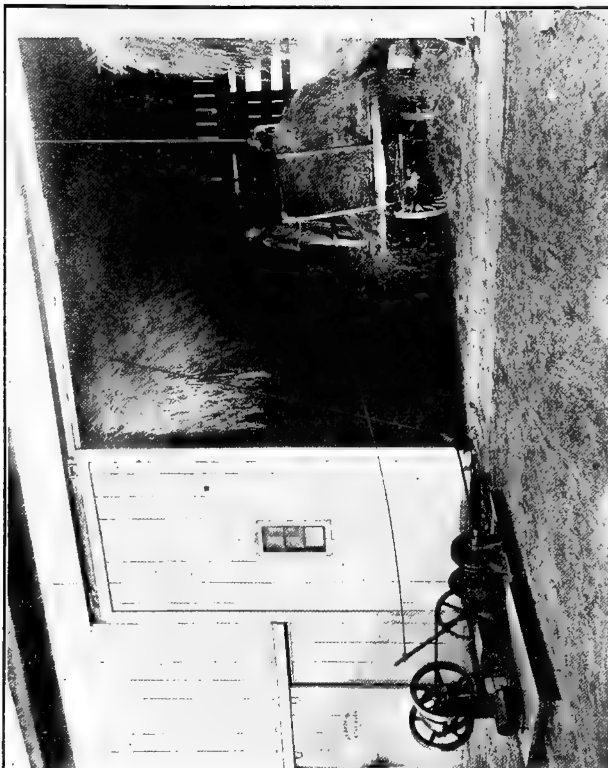

FIG. 171.—Unloading Hay by Gasoline Power Utilizing Brown Double Drum Hoist.

ends of the flooring plank to cover this bin, return the long ends to place and fasten securely; then out of the short ends construct a solid door or man-hole cover, both ends and both edges of which rest upon solid supports below. A little care in this respect may be the means of avoiding a serious accident. Never depend on dropping the short pieces into place without some means of fastening them there. Secure them with a hasp of some sort. If this fastening can be done from the lower side it will save the presence of annoying staples on the floor above.

The elevating trough should begin just below the lowest point in the hopper bottom of the bin, so that everything in it will drop into the trough. At the lower extremity a pair of sprocket wheels carry each a chain to which are attached the conveyors. The shape of these depends a good deal on the pitch of the ascent. If there is plenty of slope a very satisfactory elevator may be made of wooden slats bolted upright upon the chains; if the ascent approaches the perpendicular the regular purchased buckets, such as are used in mills, are best. They occupy less room and are so uniform in size that the spout in which they run may be a very accurate fit and so permit little grain to fall back. At the upper end of the elevator, which should go considerably above the top of all bins, a trough conveyor should be hinged in such a manner that it can be swung to discharge into any bin in the granary.

When the grain thresher is set up, ready for work, a canvas or sheet metal spout is run from the grain spout of the separator into this bin under the floor and the grain, as it is discharged from the machine, is delivered to the elevator with no hand work whatever and with the least exposure to threshing floor

dust. At least two men are saved in the threshing crew and, thanks to the gasoline engine, grain is delivered directly into the bins without carrying, without hauling and without bagging. Not even tallying is necessary. The bins are measured and the exact amount of grain determined much more accurately than in the case of ordinary machine measurements.

575. **A Tractor Mower.**—People had been making use of mowing machine wheels for some time for tractor drivers before it occurred to some one that the wheels ought to answer a similar purpose if power was applied to them while they were left on the machine. For this purpose one of the sprocket and chain drives is most convenient though not absolutely necessary. Instead of the tongue a pair of stout cultivator wheels serve the double purpose of steering the machine and of supporting the end of the sills upon which the engine is mounted. The mounting should be back far enough to throw most of the weight on the mower wheels, which are the drivers of the tractor. The pitman frame sustains exactly the same relation toward the sills which support the engine that it formerly did to the tongue of the machine, and is suspended from it in the same way.

Between the engine and the machine a countershaft should be placed. This should carry a friction clutch; also two sprocket wheels speeded respectively to the drive wheel of the machine and of the pitman. Aside from this there need be practically no change. The mower itself is fitted with the differentials and its mechanism remains almost exactly as it was excepting for the removal of the tongue and the connection of drive wheel and pitman each independently to countershaft instead of with each other.

In operating, the engine is first started with the

clutch thrown off; then as that is engaged the tractor part of the machine begins to operate, the gearing running exactly as it would with a team when out of gear. The cutting gear is then thrown into action. This machine has several advantages over one that is horse drawn, and a number of differences. If a long grade is struck the engine is not likely to gradually tire out and slow down as a team will. If it does the cutting gear will not begin to lag at the same time and so choke down. There is no necessity of stopping to rest the team at every round or two and no need of turning out before noon in the best of haying weather because the sun is too hot for working horses to endure. On the other hand it is more important that there be no hidden obstacles in the grass. A tough stubble or small stone that stops the team by stopping the cutting bar probably will not check the engine. If the knives must stop, something will have to break and it is usually some part of the machine, which was built for horses only. About the only remedy for this is greater watchfulness and cleaner fields.

576. **Two Boys and a Motor Cycle.**—There has been a good deal of doubt expressed about whether a gasoline tractor, light enough for ordinary plowed and cultivated fields, could ever be constructed to take the place of a horse-drawn cultivator. While several successful rigs have been built of a large size it remained for two southern boys to hit upon a form of cultivator specially adapted to garden cultivating. The machine they used was a motor cycle. A light frame for the usual cultivator attachments was carried before the front wheels and then sloped back along either side, the width of cut being regulated by expanding or drawing together the outer ends of these

wings through rods and levers operating between the wheels of the machine. In order to give the machine as smooth and easy a path as possible a shovel plow or double hoe attachment may be located directly in front of the front wheel and a smooth furrow with a firm bottom opened for the tractor wheels to run in; then, if desired, this trench can be closed by a pair of disks and some cultivator teeth following the rear wheel. The idea doubtless admits of some improvement, but it may easily prove to be a step in the right direction for light power cultivators.

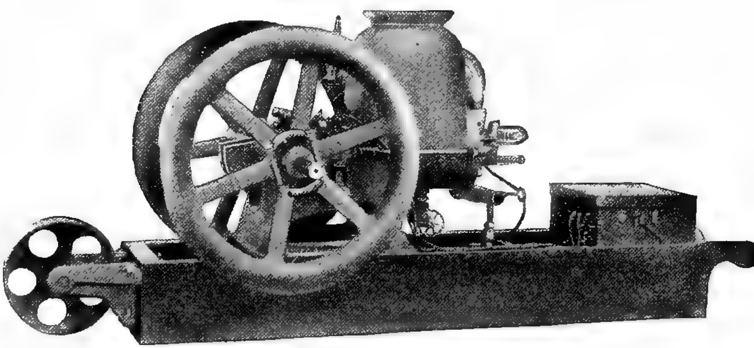

FIG. 172.—Engine Outfit Easily Moved by One Man Because of Wheelbarrow Truck.

577. **Wheelbarrow Energy.**—Several seasons ago engine makers began to advertise the fact that two men could easily pick up an engine capable of developing several horse-power and carry it where it was wanted. The weakness in this was the fact that very often the engine is wanted on the one-man sort of jobs; it was evident that some means was needed for one man to convey the engine from place to place, so it was mounted upon hand trucks. This idea had a decided advantage—and a drawback. Rolling sup-

ports invariably add to unstability. The hand trucks had to be blocked very securely or they would show more vibration than would those on sills. Some bright mind has united the two principles in the wheelbarrow truck. One end of the sills under the engine is mounted on small wheels and have their lower corners cut away so as to clear the floor easily even though the diameter of the wheels is less than the depth of the sill. The other ends terminate in handles like those of a wheelbarrow. When these handles are raised and the weight thrown upon the end supported by the wheels the engine may be moved about by one man like a wheelbarrow. When the handles are let down the deep sills raise the wheels entirely from the floor and the engine at once rests upon sills—ready for business.

578. **A Unique Fruit Gatherer.**—Who, after weary hours of climbing up and down a ladder, tugging baskets of apples with always more to be picked, has not yielded to temptation or ill-temper, and ended the job by shaking bushels of good fruit down to be picked up from the ground? Of course, it was ruinous to the fruit, but after the hard work that had been endured there was even a little satisfaction in the ruin. A device made similar to a set of horse clippers, but with shorter blade and wider teeth, may reduce both the time and labor of hand picking and at the same time do the work quite as well.

The blade is attached to the engine exactly as horse clippers are and a rod secured to the flexible shaft. A canvas tube, held open at its mouth by a small hoop, is swung to the rod directly below the blade. This may reach to the ground or, better, to the wagon in which the engine sets and that will be used to haul the fruit from the orchard. If this wagon has

been fitted out with tractor power the same engine which supplies the power can be used in picking the fruit.

The operator on the ladder hooks a rod at one end over any convenient limb and the other into some part of the canvas tube, some distance down. This relieves him from the weight of the apparatus. With the rod which carries the blade and mouth of the tube he swings the contrivance here and there, just under the fruit and as rapidly as a stem is touched it is cut by the jaws of the blade which are driven by the motor below, the fruit falling through the hoop into the canvas tube, whence it is received by the attendant in the wagon below and sorted, if dry, into the regular packing barrels. Not only does this save all loading and nearly all climbing up and down; it also avoids practically all handling of the fruit excepting the one placing in the barrel. The canvas bag or tube should be of sufficient length to admit of some slack so that the fall of the fruit will be retarded by friction among the folds. It must also be kept constantly emptied by the attendant so that the fruit will not be bruised by contact. While a device of this sort might seem rather trifling for operating with engine power by itself it is no more so than the shearing of sheep or the clipping of horses, both of which have long been done with the help of power. There is no reason, however, why the same engine should not at the same time supply the tractor power for moving the wagon about; also, for raising the ladder and swinging it from the tree while the wagon was shifted to another place. In fact, about all the lifting that goes with the harvesting of fruit can be done with a gasoline engine, and at very little expense.

579. **A Home-made Power Saw.**—As an example of

what may be accomplished by one possessing mechanical ingenuity and the ability to utilize odds and ends, which are found lying around any farm, the tractor saw outfit depicted at Fig. 169 is presented. This machine is built entirely of components which had reached the end of their usefulness on various farm machines. Common header binder wheels serve as drivers, while the front end is supported by separator trucks having narrow bands shrunk onto the rims to prevent side slip. The differential gear is on the rear axle, which revolves in babbitted boxes. The countershaft is directly under the engine base and a chain is employed to transmit the engine power from the countershaft to the differential sprocket. A jack shaft, which runs lengthwise of the frame, receives its power from a single pulley on the rear end of the engine crank shaft and drives the countershaft by a bevel gear. The reverse motion is obtained in a very ingenious manner. Two bevel pinions are keyed on the jack shaft a little further apart than the diameter of the bevel gear, driving the countershaft, which in turn drives the differential sprocket. If the jack shaft is moved endwise, so the back pinion engages the bevel gear, the machine moves backward on the road, while if the jack shaft is shifted backward so the front pinion engages, the forward motion of the tractor is obtained. A short belt, six inches in width, drives the jack shaft from the engine pulley and a jockey pulley or tightener serves the purpose of a clutch. If the jockey pulley is moved back, so that the belt is loose, the engine will run independently of the road wheels, whereas, when the belt is placed under tension, the engine will drive the conveyance. The frame is made of round wrought-iron pipe and the cooling water is pumped through it so the frame performs the func-

tion of a radiator, as well as a support for the power plant. The saw is operated in connection with a swing table which the maker considers the quickest acting and easiest handled form of saw table. The engine is adapted to use kerosene so that very cheap power is provided. A machine of this nature may be duplicated by anyone having the patience and ingenuity to contrive and sufficient mechanical ability to join the various parts together and adapt odds and ends to a useful purpose.

580. Other Home-made Conveniences.—The making of ingenious little labor saving devices, if persisted in, becomes a matter of demand and of habit, rather than of study. The occasion will supply the desire and, with that, the trained hand and brain soon find a way of accomplishment, although that way may not be exactly the same with any two different people. As surely, too, will the habit of applying power and mechanical advantage to the simplest tasks grow upon one, after it is fairly exercised, until the work of brute force and animal muscle will nearly all of it be replaced upon the farm as elsewhere through energy which originates with the brain and the intelligent directing of the forces that nature has placed within reach of our hands.

CHAPTER XXVIII.

MODERN POWER APPLICATIONS.

581. Helping the Binder.—Any practical farmer understands that the bull wheel of a grain harvester must perform two duties; first, carry the weight of the machine, and, second, supply the power required

FIG. 173.—Small Gray Motor Helping the Binder.

for operating the cutting, elevating and binding machinery; and it is this second operating strain that, more than anything else, causes the binder to choke down and sink into the soft earth, when the ground is wet or the season unfavorable. Rarely is a team stalled with a binder running empty or when the bull wheel is merely carrying the dead weight of the machine. Several years ago much of the grain grow-

ing section of the west became a veritable quagmire on account of heavy rains, and the grain was going down and shelling badly. Unless saved at once, thousands of bushels would be lost. Team power enough to drag the weight of the binders through any depth of mud could be supplied, but the instant the machines were thrown into gear the drive wheel would slip and refuse to turn.

Someone, desperate at the prospect, fastened stout iron brackets to the rear of the binder frame and set a light gasoline engine on, took the drive chain from the binder, connected the sprocket drive to the engine, turned on his power and started his teams. That idea saved the world many thousands of bushels of wasting grain that season and the same idea has been in operation in the world's great grain fields annually ever since. Even if the ground is solid it saves one or two horses out of each team and makes it very much easier for them. It is also easier on the machinery, as the motion can be regulated once and then kept uniform. There is no slowing down of the cutting bar in tangled spots where the full speed is most needed. The horses are not worn out or winded at the end of a few rounds. If there happens to be a long hard grade they do not in addition to this extra work have added to their burden the extra draught from the slower motion they are almost certain to maintain; nor is a portion of the grain pulled out or slid over. The work can be done much faster, too, because a wider cut machine can be used with the same team, the dead weight of an eight-foot cut being very little more than one of six.

A gasoline engine for this service must be light and smooth running. About three horse-power is generally used, and an engine that can be mounted on

brackets behind the binder or even set upon the table is best, as there is no trouble about alignment. Heavier engines are, however, mounted upon light trucks and dragged behind as trailers, the power being conveyed to the binder by a shaft and universal joint. When mounted on the binder they are usually set directly on the table or else placed between the bull wheel and the beam back of the axle and are connected with a chain to the small sprocket.

In 1909 the gasoline engine saved several million dollars worth of grain in the flooded districts of the Missouri river valley in this way. On account of their proven value in this field, binders are now being demanded, with the engine supplied as a regular part of the binder, but detachable, for other light work when needed.

582. **In the Hay Field.**—A light power engine set upon the frame of a mowing machine not only does the same thing for the hay harvest that it will do on the binder, but it enables the ordinary team to keep in steady operation, with little or no time wasted in turning corners or resting at the end of the swath. For this grade of work a sprocket wheel should replace the usual belt wheel on the engine and positive chain drive be used. Very little change need be made in the mower, a sprocket wheel being introduced to receive the drive chain and the regular driving gear being disconnected from the drive wheels of the machine. The engine should be mounted well back, so that at least one-third of its weight will fall back of the machine axle. As it is usually necessary to move the driver's seat back a little his weight in its new position will generally about balance the extra weight of the engine so there will be no added pressure on the horses' necks.

Many small farms have been deprived of the use of the hay loader for no other reason than because it is too heavy for a single light team to handle excepting under the most favorable of conditions. A bracket platform hinged at one end to the under side of the loader at its base and supported at the other end by small wheels forms a convenient support for the engine, which can then be attached to the ele-

FIG. 174.—The Motor Truck In the Hay Field.

vating machinery of the loader and the pull of loading the hay be transferred from the team to the engine.

583. **Making the Spreader Work.**—The manure spreader is also a forbidden luxury on many farms because of the team power it requires, although in all the list of farm machines, the gasoline engine alone excepted, there is no other that will pay for itself more certainly and readily. The work of the spreader is, however, more intimately associated with that of the team which propels it than of the binder or loader, there being no part of it that can be operated to ad-

vantage independently from all of the rest. The engine may be applied to one or more wheels as a tractor or it may be attached to the spreader mechanism only and through the medium of a governor pulley which would admit of the engine exerting its full pulling capacity and at the same time guard against its being overloaded and choked down. Once started, a three or four horse engine will take off so much of the load from the team that there is no necessity as a rule for the latter to stop. With a little care on the part of the driver the team and engine may be kept working so nearly in unison that neither will be overloaded and the advantage of the spreader will in this way become available upon thousands of farms that are now getting along the old, hard and extravagant way.

For use with the spreader the engine should be mounted on a platform at the extreme front end of the box and across the top, so as to be above all the scatterings that might otherwise interfere with some part of the engine, or the connecting gear.

584. **The Short Power Wagon.**—It is the experience of everyone that, while an ordinary team can haul all that the farm wagon should be expected, as a rule, to carry, there are times when it is economy to overtax the usual capacities of the farm team. The pull may be over good roads but a long distance; or the roads may be too heavy for a team to handle enough of a load to make the trip justifiable; still, it may have to be made.

The gasoline engine, applied as a tractor, can make possible a full profitable load under conditions that would otherwise make only a half loaded wagon available. It will also supply that unflagging energy that will enable a team, without undue fatigue, to convey

their full capacity for a long distance. With a good driver in control, the engine and team may become valuable supplements of each other and do work to good advantage, that neither one would do as well alone. Often the slippery track will not permit the drive wheels to hold enough to take the wagon on tractor power alone when a very little help from the team will relieve from that last pound of pull that

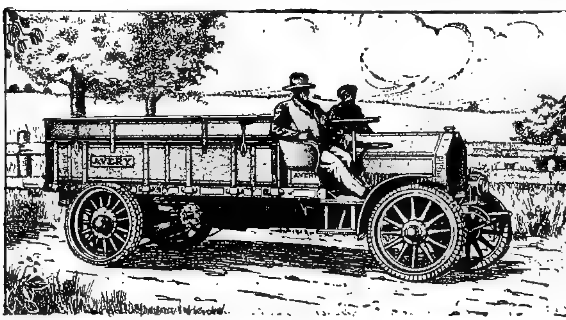

FIG. 175.—The Modern Connecting Link Between Farm and Market.

breaks the hold of the wheel lugs. Often even a little help from an untiring source will prevent the team from wearing out.

Especially in going to market, where the pull is long and steady rather than hard, the engine will enable the team to endure a load that could not otherwise be taken more than half of the distance, without cruelty to animals.

585. **At Threshing Time.**—All energy, unless being continually overtaxed, is judged by the way it meets the calls of emergency, when some unusual demand is to be met. The farm equipment that goes smoothly, most of the time, may be found seriously wanting at

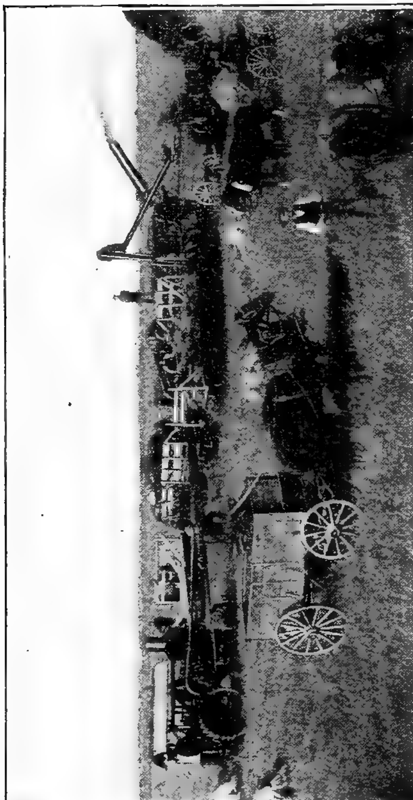

Fig. 176.—The Gasoline Engine Indispensable in Threshing Time.

such unusual times of stress as threshing time and may have to draw heavily for help upon the resources of the surrounding farms. For the fully equipped farm only a little of this is necessary. A good gasoline engine of very moderate size, but well managed, can do away with much of the old time calls upon the neighborhood and make each farm nearly, if not quite, self-sustaining in the matter of labor equipment. Many farms of the future will have each their own threshing equipment quite as certainly as they now have their own provisions for storing their own hay. Stripped of its portability and its wholesale capacity, the grain separator is not nearly so complicated nor so expensive as the binder or the mowing machine. When one is found built into every barn, the grain will be hauled from the field and unloaded directly into the separator without any intermediate handling. Such a process will not be as long or as hard as the present one, for both grain and straw will be elevated by machinery.

Even with our present day system of neighborhood threshers, the gasoline engine can be made to take the place of most of the hands. We have already seen how it may supplant the two or three men at the grain. The modern wind stacker, directed into a tight mow and with its discharge end hung to a pulley traveling back and forth along a steel track, can be made to distribute the straw well over the mow without much attention. With the help of the engine, when hauling in and storing the grain, the mows may be so located that gravity may again be utilized to the best advantage and, by means of sloping floors, one or two men can frequently receive at the foot of the slope and drop into a conveyor almost every sheaf in the mow. Two hands, at most, would be ample

for the grain sheaves. The gasoline engine, once the sheaves were dropped into any part of the conveyor trough, would take them to the machine. There are mechanical band cutters on the market; one of these, at the end of the conveyor, would dispense with another man. In all, we have one or two men in the mow and another one to watch the operations in the stack and bins; that is about all that are needed, providing all the possibilities which the gasoline engine makes available are taken advantage of. Let anyone who is inclined to pronounce such arrangements visionary take a trip through any other kind of factory and note how completely even the most trivial operations are made automatic and mechanical before he decides that it is impracticable to put our great farm factories upon this same carefully constructed business basis.

586. Harvesting the Corn Crop.—Because silos and corn harvesting by machinery are of such comparatively recent origin, we have had fewer old prejudices to overcome and it has been comparatively easy for people to adopt methods that are well advanced in their mechanical perfection. Already we have corn harvesters at work cutting by the acre as we once cut by the hill, and we have them operated by gasoline engines both in the form of tractors and of small power helpers auxiliary to the team. We have tractors hauling the crop from the field after having loaded it on with their own power. We have ensilage cutters with self feeders, which require only a little hand work between the time when the shocks are taken from the load and the moment when they are finally deposited, shredded and with the ears separated out and husked, if we wish, in the silo or the mow. We have elevators and wagon dumps that

will deposit the husked corn, a wagon load at a time, in the cribs. We have shellers to shell it without our once touching it by hand, and mills to grind it; or, if we wish, it may go to the mill cob and all. From the time the seed is poured into the planter, until it has been raised, harvested, ground, fed, and converted into beef, it is necessary for the human hand to come in contact with it hardly at all. Surely this is a triumph for farming machinery along this one line, which ought to convince the most skeptical that equal results may be obtained along any other. But only a little of all this could be accomplished without the help of power—mostly gasoline power.

587. **Hauling by Cable.**—Before the days of tractors, hauling and even plowing by cable was in common use, and even yet, in some parts of the world, it is resorted to, quite a little. It has one great advantage over tractors, the difference between tractor and draw-bar efficiency which, in the case of most engines, amounts to 30% or 40% of the entire efficiency of the engine. Cable hauling, however, like coasting, has certain drawbacks in relation to the profitless and sometimes difficult "trip back up the hill." Where the engine can be located central to considerable work and within reasonable distance, such as where clearing off a piece of land from stumps or stones, the cable may be used to reasonable advantage; but, for ordinary conditions the tractor, though it uses up a good deal of power in its own propulsion, is the most economical because the most efficient; the engine power saved by the cable method having most of it to be made up by the extra man power required in the handling of the cable.

588. **What Gasoline Is Doing to the Road Question.**—It was the bicycle first, and afterwards the

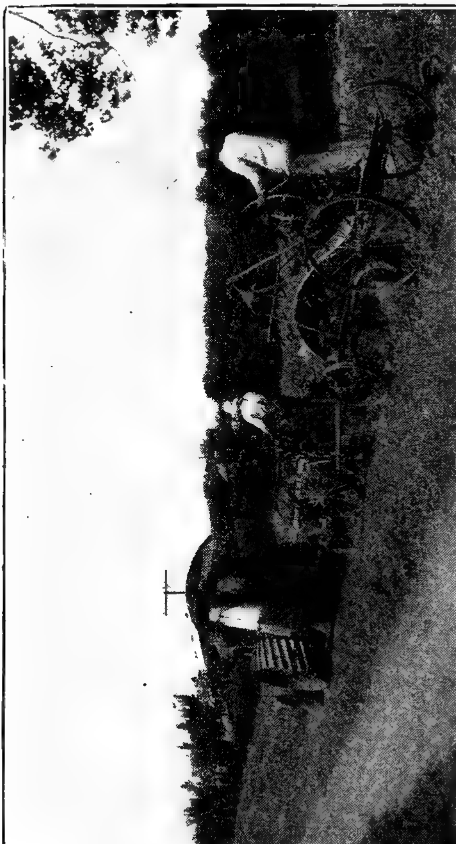

FIG. 177.—Better Roads Made Possible at Small Cost by Gas Tractor Outfits.

automobile, that impelled the recent countrywide movement for better roads. A little sectional feeling may have been engendered at the start because a few city people out for pleasure first made known to the world, with perhaps unnecessary criticism, the discovery that the country roads were, some of them, bad; still, the farmer was not long in deciding that the same highway condition which was keeping the city pleasure seeker out of the country was making the distance between himself and his markets even more objectionably great, because his use of the roads was largely a matter of business instead of pleasure.

Since it was through the agency of gasoline that this great problem was first convincingly presented, let us see what progress gasoline has made in solving it.

In Bement township, Piatt county, Illinois, which now boasts of some of the best dirt roads in the state, a 45 H. P. gasoline tractor is used first to clean out both ditches thoroughly with the grader, then to level and crown the center of the road with the leveler, and last to press it into a compact surface that is almost waterproof by going over it with a 6-ton roller. This is done at a cost of $2.40 a day for coal oil, 55c. for gasoline, $1.00 for lubricating oil and the wages of two men; say $8 in all. The result has been some of the finest dirt roads in the state of Illinois, 35 feet from gutter to gutter and from 16 to 20 miles of them completed each day. Three years ago these same roads were often all but impassable. Now the only attention they require is an "occasional leveling after a rain to maintain their crown."

Comparing these results with those obtained by other methods, including one or two expensive steam outfits, the road commissioners state that they have

moved more dirt in two years with the gasoline tractor and have accomplished more with it than in the entire twenty years preceding. Steam power they declare to be much more expensive in wages, fuel, running expenses, and wear on engine, both while in use and specially when idle.

589. **Fighting Weeds.**—For those highways, the surface of which is unsuitable for road making, there are gasoline outfits that gather up the loose dirt in the roads and ditches and deposit it either into a wagon driven at the side of the rig or at the side of the road beyond the ditches. This not only disposes of the wash from the ditches, which has left the road bed because it is too unstable in nature to be of use; it also, in part, buries and discourages the weeds and brambles so prone, if left to themselves, to come up along the space between the ditch and fence. A more important weed-killer, however, is found in the spray pump, which, as we have already seen, is operated best by engine energy; the efficiency of the work against the weeds, without injury to the growing grains and grasses, in the case of field work, depending very much upon the solution being applied in a very fine spray driven with a good deal of force—at least 100 pounds pressure to the square inch being necessary at all times—and with enough pumping capacity to distribute from a barrel to a barrel and a quarter per acre, 52 gallons being reckoned as a barrel.

In preparing the solution, too, the energy of the engine is of direct assistance, especially if copper sulphate is used in preference to iron sulphate, as it dissolves with greater difficulty, although 10 or 12 pounds of it, if really pure, are equal to perhaps 100 of the iron salt. Where horses are used as a motive power, it is customary to take on a barrel or two of the pre-

pared solution at a time and then have more of it under preparation with hand agitation of the liquid, at different points of the field. Where help is scarce, this is not always convenient, and where it is plentiful, we still have another case of using intelligent man energy for a purely mechanical task that a machine would do as well and even better. With the tractor a larger quantity can be carried without an overload and a couple of barrels of the complete solution in one tank; in the other the same amount, in process of preparation, will only keep the tractor moderately busy; the same engine that carries the tanks about supplying the pressure for spraying and running the agitator in the mixture being dissolved. With plenty of carrying power, a third or reserve tank may be advantageously carried, if the fields are large. Then as soon as one tank is emptied the second one can be switched to the spray nozzle and the refilling of the first done ready for beginning a new solution without having to wait until the stationary water supply is reached at the end of the field. By this means both of the working tanks may be kept supplied with material for their respective tasks at all times and the reserve tank replenished at the convenience of the operator.

Another advantage that the engine sprayer has over one driven by horse-power is the fact that there is no animal life to protect against the effects of the drifting spray. Horses used in spraying must be kept closely blanketed and even then are more or less exposed to injurious effects, as they are continually breathing in air that is more or less charged with a poisonous mist.

590. **Ditching.**—In a good many places tile drainage is a necessity if we would obtain full 100% re-

sults; in very many it is a material advantage. Always, though, it is an expensive and laborious task, when done by hand labor. Intelligent workers are specially hard to get at a reasonable price for ditch-digging, but it takes a certain amount of intelligence to finish the bottom up to the grade. A machine will do this much cheaper and with far more uniform results. Gasoline ditching outfits are now made that not only dig the ditch any desired depth, but at the same time lay the tile and fill up the trench after themselves, a six to nine-foot ditch being dug by some of them at the rate of 120 feet per hour. Under specially favorable conditions much greater results have been reported. With the advent of cheaper ditching, more of it will be done, many acres of land, that has been, hitherto, untillable or only partly so, will be reclaimed and thousands of acres will be sweetened and rendered more productive by making it possible to work them more promptly at the proper seasons and gaining control of underground moisture conditions.

591. **The Farm Roller.**—Friction is the great energy absorber wherever one moving body comes in contact with anything that supports it and this is quite as true of all contact with the earth as it is of journal boxes in machinery. In just the same way, too, can this power destruction be decreased by smoothing the surfaces at the points of contact. While we cannot lubricate the track of the binder across the field as we can its bearings for the axle, we can decrease to a very great extent the friction strain by rendering the road under the wheels as firm, smooth and level as possible, an efficiency of anywhere from 10% up to 60% or 70% being possible in this way, the gain depending a good deal on the amount of necessity for it. Of all known implements

of the farm, the roller is the most effective in doing this.

Horse drawn rollers have a number of drawbacks. In the first place, the ground that is mellow enough or soft enough to respond the best to the roller's pressure is just in the right condition to be injured by the sharp-cutting hoofs of the team. If the ground is firm enough to withstand the footmarks of the horses it requires a heavier roller than the ordinary farm team can handle to do the work in a really thorough manner.

Power driven rollers may be made a part of the power plant itself, the broad, smooth wheels that will entirely cover the ground the tractor covers being substituted for the usual tractor wheels. Because of the broader surface pressed upon there is no sinking below the general surface level in spots as in the case of a horse. Because of the unlimited horsepower that may be turned loose in a tractor there is no limit, within reasonable efficiency, to the weight that can be brought to bear directly upon the ground to be rolled. Where tractor farming has been in use for some time the fields will be found smoother even without the rolling, partly because of the continuous leveling off which traction farming insures and partly on account of the more thorough system of harrowing and cultivating all the plowed fields are certain to be given and because, in order to get the work done at all, the ground does not have to be worked out of condition.

592. **Sheep Shearing.**—Although sheep shearing is not generally thought of as one of the heavier tasks of the farm, it is safe to say that there are few others which leave the operator more tired when night comes, the work being particularly trying on the

muscles of the arm and wrist. One of the most effective and inexpensive sheep shearing outfits ever brought to the writer's attention was constructed by an Ohio farmer and consisted of a 1 H. P. gasoline engine mounted in a light wagon and belted to the shafts which operated two horse clippers. Very little alteration was needed excepting in the shape of the blades. The framework which supported the shearing arms was adjustable and could be readily moved to the extreme end of the rig when in operation and slid forward to the center of the buggy box when on the road. The entire outfit is easily hauled about with one horse, and working full capacity it uses less than a gallon of gasoline per day.

593. **In the Poultry Yard.**—In the poultry yard, aside from the usual work of shelling and grinding feed, the uses of the small power gasoline engine are numerous. Bones, instead of being buried or burned or thrown about the place, are thrown into the hopper of the cutter and reduced to good poultry tonic by the boys of the place for the fun of seeing the engine go. The straw is cut into short lengths and clover hay chaffed into meal. Water can always be handy and the roosts and inside of the building kept thoroughly sprayed out and cleansed and disinfected. Outside, the whitewash spray pump takes the place of the brush, and fills the crevices better besides doing it so much more quickly that it is done with greater frequency. Coops and all parts of the poultry plant will be kept in better repair because there is more time for it, and it can be done with so much less work.

594. **The Road to Market.**—Aside from the things we eat, the value of what the farmer produces is after all finally determined largely by the proximity of his markets and his means of reaching them. Distance

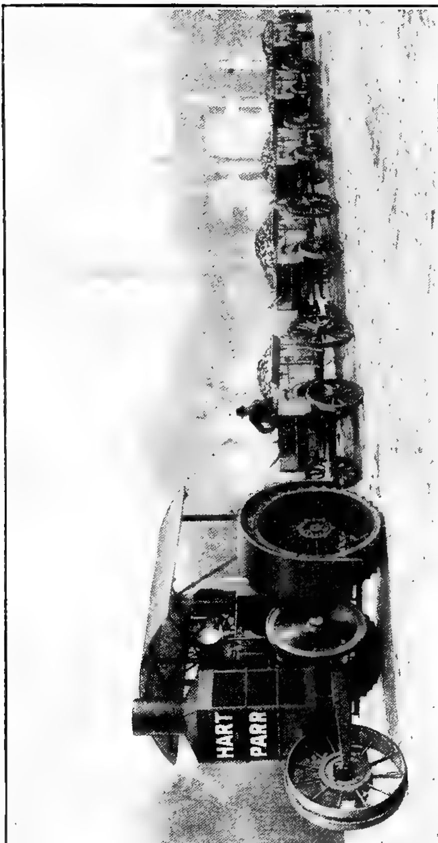

FIG. 178.—The Gas Tractor Shortens the Road to Market.

alone is not the measure of remoteness. An unbridged river, with no boat at hand, might cut a serious amount of profit off from produce that would have a high commercial rating on the other side of the stream. The stream of mud, the channel of impassable roads between the farm and its nearest market has sometimes been an equal menace to profit; but now that the mud is being removed, and the bad roads in some measure done away with, actual mileage distance can be more directly reduced. Even this the gasoline engine has done much to overcome.

Taking the country over the average team haul of wheat, to place it on the market is 9.4 miles, at a cost per ton of 19c.; the average haul of cotton has been 11.8 miles, at a ton mile cost of 27c. After a limited distance the cost of hauling by team increases rapidly, as the reasonable endurance limit of the horse is approached. The cost of hauling by motor decreases with the distance, the main expense being the handling of the load at either end of the trip. On the road the cost is very slight. This fact is an important one, both to the farmer and the man to whom he sells, because, as the population of the cities increases faster than the producing capacity of the territory around them, a larger area must be levied upon for the same quantity of supplies for each person; that is, the haulage distance is becoming greater. It has now outgrown the capacity of the horse and requires that of some other power. To a great extent railroads have taken and will continue to take this place; still there must be some means of connecting even the local station with the farm, and more and more is it becoming necessary for the farmer to handle his produce in the most economical manner, by taking it in larger quantities; by reducing the time required for each trip.

Again the gasoline engine has met this new farming condition. With the automobile at hand the road to town has been reduced at least 60 per cent., or, put in another way, the area of farming land now within reasonable market distance from the city is increased from four to eight times. In the matter of truck farming alone the average haul was formerly 3 miles, a total acreage of 28.26 square miles. Improved roads finally raised the average haul to 6 miles, and threw open to each market an available area of 112.9 square miles. In these same good road communities the automobile has considerably more than doubled this.

The above facts are considerably modified by the additional truth that, while only 80 years ago but 4 per cent. of the population of the United States lived in cities, that percentage has now increased to over 40 per cent. This means a smaller proportion of agricultural producers; about 30 to every 100 inhabitants, as against a former 96 out of 100. The demand, then, is extending, and, while the average production per acre has also increased, the necessary hauling distance, the territory that must be levied upon by each trade center, has been extended, from the capacity of the horse to that of the automobile and the motor car. Through good roads the cost per ton mile of horse haulage, as has been proved by experiment, may be reduced to 10c., but the cost of the same for a motor car is already only 3c. over good roads, a difference of $840 per 1,000 tons of country produce delivered, to be divided between producer and consumer, figuring on a twelve-mile haul.

595. **Building Home Memories.**—"My recollections of the farm," declared a successful merchant several years ago, "consist of going barefooted through the frosty grass along about daylight after the cows; in

having to carry the wash water up a steep hill from the spring before breakfast, in order to get time for gathering sheaves after the cradlers and binders in the stubbly grain field the rest of the day; of having to go out after supper for another load of hay, and then of hunting up the cows again and helping

FIG. 179.—Home Memories.

to milk them until after bedtime; of seeing my mother, sober-faced and weary, dragging herself, day after day, about the house with her entire life centered upon the drudgery of her kitchen and all the rest of the world a closed book to her; of seeing my father, broken down with long hours and hard work, finally relieved of the task of paying for the old place—just a few months before he died. I know that those early discouragements hardened me to meet those I have since met; that the strenuous life I lived in my childhood did much to fit me out with habits of industry that have brought me success—that it equipped me

with a bitter prejudice and an intense hatred of farm life. I know that the conditions there are different now, but my whole life, in spite of that, has been shadowed in a measure by certain memories which I cherish, against my will, of the old farm. The man or woman who has been deprived of sweet home memories in childhood has missed the best of life, and I still hate the farm for so depriving me."

That merchant was right and wrong; wrong in permitting a prejudice to distort the experience of an individual into a type condition; right in the extent to which old home memories may exert their influence and teach their lessons long after the home itself has nothing left but memory. No material results can ever equal the far-reaching influences they may be made to wield upon the man or woman all through life, if rightly exerted upon the child. Is not, then, all that will help materially in elevating those home memories, in lifting them out from the slums and ditches of drudgery more potent in the uplifting of the child than any material wealth that we can give him? So long as prejudice endures, the industrial status of farming will be judged by its influence upon the memories of our young people—whether it leaves with them impressions of a drudgery that is little above that of the animals of the field, or whether the recollections are linked up with intelligent application, a busy life, perhaps, but one wherein the superior brain power which has been given to the human race is not degraded into sheer brute force. On these old memories depends not only the industrial choice of the boy, but the respect of the man for farm work, country life, and the old home; and no other single phase of the standing of agriculture in the world of industry so surely determines her place in the realm

of intelligence as does the story of the power that turns her wheels; whether it be expressed in terms of brute force or intelligence; of animal muscle or of that greatest achievement of the human race—mechanical power.

CHAPTER XXIX.

THE IDEAL FARM.

596. A Look into To-morrow.—It does not seem inappropriate, even in a semi-technical work, this hasty glimpse at the ethical side of life, when we consider that it is a legitimate feature of all life of which the farmer no longer has occasion to be deprived. The yesterdays of agriculture were days of toil and patient effort; those of to-morrow, we who have faith in her believe, will be days of achievement. One of the most coldly practical problems of to-day, then, is best answered by a brief study of the path directly ahead. Along what industrial lines may we best advance; what use shall we make of this new mechanical force—power?

597. Summary of the Complete Farm Home.—Somewhere, looking into the future, we can see, instead of the overworked, heat-tortured horses of the past, a vision of unwearying engines drawing behind them the most efficient weapons of conquest in the world's battle for bread which the world's best brains can produce, the speed, the depth of culture; the best mechanical aids to plant growth that can be produced, without regard to capacity limits, and only considering highest efficiency. Season conditions will count for little, because, with the forces in hand, the man work of weeks may be done in a day, perhaps in an hour. No form of mechanical efficiency, whether it be deeper cutting, more complete pulverization, or a

more thorough mixing of air with every grain of earth, will be lacking. The factory of yesterday and of to-day, so perfectly equipped to the finest details in quickly, cheaply, and effectively carrying out every constructive process that requires to be done in the conversion of raw material into the finished loaf or fabric, will just as effectively to-morrow perform every needed operation in converting the elements of the earth and air into her useful products. The one constructive word of the future will be efficiency, instead of capacity, on the farm as elsewhere. Greater and better crops will be raised, and raised more cheaply, because the soil will be, not once, but always put in the best possible condition for feeding plant growth. The climatic and weather accidents of agriculture will exert no more important influence upon the output of the farm than of the factory. A complete system of drainage will remove the terrors of excess rainfall. Irrigation will guard against dangerous droughts. Frosts will be controlled, insect pests conquered, fungus diseases overcome, most of them, perhaps, through the pumping systems of to-day—and of to-morrow—all made possible only through this general application of limitless power.

The harvests will also be under the most complete control; the reaping, the gathering in, under the best of mechanical conditions; the separating of the grain from the chaff; the conversion of each to its own most efficient use; the conservation of it all with chemical exactness. Because of available power the seed bins that are filled with grain that is faultless will be the rule. Because of the better developed and better used cleaning machinery the crops of the field will supply very little that is weeds or waste. The balanced ration will be the rule instead of the exception; it

will insure a richer production of milk and of butter fat which engine driven mechanism will work up to the last degree of food efficiency.

In the house, as in the fields and barns, this glimpse into the future shows equal changes. Work is not eliminated—who would wish it—but it is made to produce a higher degree of efficiency, and without sacrifice of the intellectual and the ethical side of life. The tasks of the day will be of a nature that will expand, broaden. Life will be uplifted by them to a higher plane instead of feeling that constant tugging downward to a level with animal life. Effort will mean achievement and duty growth;-growth not alone of the biceps or the pocketbook, but mind growth, soul growth, greater wealth of independent thought, a working out along those lines of inspiration that, in the fetters of yesterday's drudgery, were merely air-castles; that in the atmosphere of this new inspiration become the true ideals of hope for us to work out.

598. How the Gasoline Engine Makes It Possible.—How does the gasoline engine make this possible? By intelligent work; by releasing us from the fetters of muscular limits. With the constant grind of getting the most pressing tasks done as well as the circumstances will permit removed, there comes in its place a new pride in reaching out toward the very best results that can by any possibility be attained. The soul-killing contest with hard necessity will become a spirited rivalry with progress, a desire to test her every possibility. Animal life considers only the ways and means of getting a living. Intellectual lives are constantly concerned in getting the best possible values out of life, the values weighed by constantly broadening standards and the best moral ideals.

599. When Dreams Come True.—It is the old

story of the man with the hoe against the man with the automobile. The ideals of the one are controlled by the limiting capacities of his own physical endurance; those of the other are expressed in terms of the world's possibilities which are stretched before him, and the world constantly widens out to him as he advances. To the man in the ditch the sunset tells only a story of supper-time and another completed day of toil. To the man who directs him it brings glimpses of eternal beauty—lifts him into a new life of ethical enjoyment—out of his own.

CHAPTER XXX.

TABLES AND FORMULAS.

600. Electrical Terms Defined.—Water is readily compared in much of its behavior with air, steam, and other invisible vapors and gases. For purposes of explanation it may be considered in connection with another kind of invisible fluid, electricity; at least the exact meaning of some of the arbitrary terms used in electrical measurements may be more easily understood by a comparison with the better known qualities and measurements of water.

The Volt.—The tendency of water to rush out from the end of a pipe which conducts it from an elevated tank to some lower level depends upon the pressure of the column of water behind it and we speak of it as so many **pounds** pressure. The tendency of the electric fluid to rush from a higher to a lower potential —that is, to equalize the two—we measure and speak of as so many **volts** pressure, meaning much the same thing that we mean by **pounds** pressure in the other case. The volt is the electrical term denoting measurement of pressure or intensity.

The Ampere.—If the end of the pipe were left open the water would not all be able to escape at once, but would have a rate of flow which would depend upon the size—that is, the carrying capacity—of the pipe and the pressure back of it. The electrical fluid also has its rate of flow through an electrical conducting medium, say a wire, to the measuring unit of which

we apply the term, not of gallons but of amperes. The ampere is the electrical term denoting the unit for measuring the rate of flow in the electrical current.

The Ohm.—No more than a certain quantity of water per minute will pass through a pipe of given size so long as the pressure is the same, but by increasing the elevation of the tank or by closing its top and forcing air or steam into it or by increasing the pressure in any way, we can force a greater amount of water through by increasing the rate of flow. This proves that there has been a certain amount of resistance to the flow which the greater pressure in some measure overcomes. That resistance is most of it friction. There is also a resistance to the flow of the electric current through the wire which we measure and speak of as so many **ohms** resistance. The ohm is the unit with which we measure the resistance or friction of the electrical current. The resistance to the water depends upon the size and the shape of the pipe. The pressure behind it determines how rapidly it will be overcome. The resistance to the electric current depends upon the size and the nature of the wire, some kinds of material presenting more electrical resistance or friction than others. How that resistance is overcome depends also upon the pressure behind the current. The size and length of the pipe and of the wire influence the amount of resistance in both cases. The ohm then is the electrical measurement unit of resistance.

The Watt.—When the water flows from the pipe against a wheel its force enables it to turn the wheel or do work. The amount of this force depends upon the quantity of water being discharged and the rate at which it is flowing. We often speak of this energy in terms of horse-power. When electricity is con-

ducted against some mechanical device which it moves we measure this working energy in terms of the watt. It depends upon the quantity and rate of electrical flow, as in the case of water. The watt is the unit of electrical energy and is the product of the volt and the ampere.

601.—Mutual Relation of These Measurements.— These units of electrical measurement have certain fixed relations with each other as well as with non-electrical measurement units. The volt is the force required to send one ampere of current through one ohm of resistance. The ampere is the current which one volt can send through one ohm of resistance. The ohm is the resistance which one ampere meets when impelled by one volt of force.

One electrical horse-power is equal to 746 watts. One thousand watts make one kilowatt, which is equal to about 1 1-3 horse-power. This is the standard unit of measure applied to the dynamo.

From the above units it is possible to make most of the calculations needed either in gasoline engine ignition or in the electrical equipments which have been described as direct outgrowths of engine conveniences. The volts multiplied by the amperes give the number of watts, which in turn can be reduced to terms of horse-power or of kilowatts, always remembering that, owing to friction, resistance of wires, etc., it requires more than a 1 1-3-horse-power engine in practice to drive a kilowatt dynamo.

The ordinary 16-candle-power carbon filament lamp requires about 50 watts. The 15-watt (low voltage) tungsten lamp gives about 12 candle-power and the 25-watt lamp 20 candle. Most small residence lighting plants are run at 30 volts. Fifty 12-candle-power tungsten lamps can be operated with a 2-horse-power

engine at a cost of little more than 5 cents per hour for fuel. If not charged with more than its rated voltage a lamp should be good for from 600 to 1,000 hours.

602. **The Fire Hazard.**—Fire insurance companies were inclined at the first to be unreasonably exacting in relation to all things using gasoline, in part perhaps because the nature of the fluid is so generally not understood. They have had to relent in regard to the use of stoves. They are relenting toward gasoline engines, because the general pressure is so great that they must either come with the popular movement or be left behind. Some general rules of installation have, however, very properly been adopted by the National Board of Fire Underwriters, which every gasoline engine owner ought to read and observe. A copy can be obtained of any fire insurance agent. The substance of the more important rulings is here given.

Location of Engine should, if possible, be on ground floor; if a wooden floor, 24 inches outside of engine must be protected by metal. In shops containing dust and inflammable material the engine must be enclosed in fire-proof compartment, opening to outer air at floor and ceiling.

Supply Tank underground, if possible; at least below level of lowest feed pipe and 30 feet or more from building; or tank may be in fire-proof ventilated vault or building with tank below level of lowest pipe.

Piping shall be as direct as possible, with tested pipe only, and both feed and overflow pipe sloping so gasoline will all drain back into tank. Pipes must not be in trench occupied by other piping and openings through walls for their admission shall be se-

curely sealed, water and oil tight. Vent and fill pipes jacketed to prevent freezing.

Muffler on a firm foundation at least one foot from all combustible material.

Exhaust Pipe must extend outside building and 6 inches or more from combustible material. If carried through floor or partition, surround with metal thimble at least 6 inches bigger, the vertical section through floor covered with fire-proof covering. It must not discharge into chimney.

Care and Attention.—Cylinder, valves and exhaust pipe to be cleaned as often as fuel renders necessary.

Electric Wiring Rules.—A set of rules regarding the construction of gasoline engines is also issued and a list of all those engines approved by the Association of Underwriters also has quite an extended code of rules relating to the electric wiring of buildings, only a small part of which are digested here. When observed, they render electric lighting much safer than ordinary lamps.

Nothing smaller than No. 14 wire allowed except for fixtures and pendent lamps. Joints must be mechanically perfect and then soldered. Wire must not be laid in plaster or cement. Side wall wire must be protected by boxing or iron conduit 5 feet above floor; floor wires must have similar protection, an inch air space all around wire in boxing being required. The maximum current allowed a rubber insulated No. 14 wire is 12 amperes, or 16 with other insulation; No. 12 wire permits 17 and 23, respectively, and No. 10, 24 and 32 amperes. All wires must be insulated according to approved specifications. Where passing through walls, partitions, floors or timbers, they must be carried in porcelain or glass bushings which reach entirely through. No wire shall be permitted nearer

than one inch to metallic or other electrical conductor without being threaded through porcelain or glass or with some non-conducting or non-absorbing material between. Many special rules in relation to "concealed" wires, etc., and applying to all conceivable cases make it advisable for those who have much electric wiring to do to obtain a copy of the rules in full. In motor wiring underwriters have a general rule requiring all motor leads to have a carrying current capacity of 25 per cent. more than the full load rating of the motor, even though the full load is seldom given.

603. Fire Fragments.—In case of a gasoline fire don't use water. Use sand, sawdust, earth or flour.

In case of a kerosene fire don't use water. Use the same as for gasoline.

In case of an alcohol fire USE water freely. It unites with the alcohol at once.

If the clothing should catch, do not, under any circumstances, run downstairs or out of doors. The first will bring the flames about the head, and the second will fan them into greater life. Lie down; wrap closely in heavy rugs, blankets, or carpets. Keep the head down constantly, as all flames tend to shoot upward, and the most immediate danger is from inhaling them.

If the engine room or building gets on fire keep cool; keep doors and windows shut. If caught inside, keep near the floor and get to a window at once. At all events, keep as far away from the gasoline supply as possible.

604. Heat Values.—A British thermal heat unit (B. T. U.) is the quantity of heat required to raise one pound of pure water one degree Fahrenheit at or about 39 degrees. Like all other standards of weight

and measure it is a purely arbitrary term used for the unit with which we compare and measure heat.

1 B. T. U. equals 778 foot-pounds.

1 H. P. equals 33,000 foot-pounds per minute.

Therefore 1 H. P. equals 42.42 B. T. U. per minute; that is, 33,000 divided by 778.

Of the more common engine fuels gasoline contains from 18,000 to 22,000 B. T. U. per pound, gasoline vapor the same, petroleum from 18,000 to 20,000.

605. Thermal Efficiency.

Heat converted into work	25	per cent.
Heat lost through walls and cooling system	50	"
Heat lost through exhaust	15	"
Heat lost through friction	10	"
	100	

The average thermal efficiency of gas, gasoline and oil engines is around 20 per cent., and the reasonable range from 10 to 27 or 28. The real efficiency of usefulness can be somewhat increased by utilizing the waste heat for other purposes, but seemingly not at present in the engine.

The thermal efficiency of the ordinary steam engine is seldom more than 12 per cent., excepting as use can be made of the exhaust steam. Triple-expansion steam engines using steam pressure of 200 pounds per square inch or more sometimes reach nearly or quite 25 per cent. of thermal efficiency.

606. Horse-power Formulæ.—To compare four-cycle engines.—Square the diameter of the piston in inches, multiply by the number of cylinders, the length of stroke in inches, the revolutions per minute, and divide by 16,000.

Rule of the Royal Auto Club.—Add the diameter to the length of stroke, square the sum, multiply by number of cylinders and divide by 9.92.

Another rule.—Multiply the radius (half the diameter) of the cylinder by the stroke, then by 3.1416 or 3 1-7. This gives the total cubic inches. Divide by 10 for horse-power.

Another.—Square the diameter, multiply by stroke, then by number of cylinders; then divide by 12.

By working out these different formulæ it will be seen that there is quite a wide discrepancy in results. The only really trustworthy test is the brake test, and even that is only relatively accurate.

607. The Brake Test.—A home-prepared brake test may be rather easily applied by fastening twine or rope to the crank shaft of the engine in such a manner that it can be wound up like a windlass. This may be done by rigging an extension of the shaft beyond the fly wheel. The twine should be free from knots and should be lowered out of an upper window of the barn or some high place in which a pulley can be fastened for the string to run in. At the lower end a weight is attached that will just cause the motion of the engine to slack down but still continue to run. Note the exact position of weight and accurately note the time in which this weight is wound up to the point from which it is suspended, then measure the distance it is raised. Multiply the weight by the distance it has been raised (the work done by the motor) and then divide by the number of minutes or the fraction of a minute it has been in doing it. The result will be the number of foot-pounds lifted by the engine in one minute. By dividing this by 33,000 the number of horse-power can be determined.

608. The Prony Brake Test.—The prony brake is

the standard popular means of determining the real power of an engine at the belt wheel, two forms of which are illustrated in chapter XIV of this work. A is a timber (Fig. 82) cut to fit over the belt pulley of an engine. To the lower side is attached a wide leather or heavy canvas band by means of two springs, the belt being passed around the wheel and secured at the other end to a bolt, C, which may be shortened slowly by turning down the nut. Just three feet from the vertical line which passes from the timber downward through the center of the engine shaft, the other end of the timber is supported to a spring balance—one with a capacity of 25 pounds is sufficient for a small engine. In case the spring balance is not at hand a pail, working over a pulley and into which weights may be dropped, will do as well.

The engine is started with belt band loose so as not to interfere; then nut at C is taken up until band tightens so that the engine begins to slow down. Note the reading on the balance, which is the downward pull the engine is exerting on the band; then with a speed indicator take the number of revolutions per minute the engine is making. If no indicator is handy tie a bit of string to one of the slow-moving shafts which is geared to the crank shaft, and count the number of revolutions per minute that it makes. After stopping the engine turn the wheel over by hand and count the revolutions necessary for it to make while the string and shaft are revolving once. The number of revolutions the small wheel makes in one minute multiplied by the number of times the fly wheel revolves to each revolution of the small one will give the number of revolutions of the belt or fly wheel per minute when the test was being taken.

The pull on the balance (or the weight in the pail)

which the engine exerted represents the energy with which it tried to swing the weight around in a circle, the radius of which is the distance from the center of energy or the center of the belt wheel to the point where weight or balance was attached, in this case three feet. Twice this distance or six feet would be the diameter of the circle, and this multiplied by 3.1416 gives the circumference of revolution or the distance through which the engine was exerting its pulling energy each revolution. If we multiply this result by the number of revolutions made per minute we would get the total distance through which the weight was lifted in one minute and multiplying this by the number of pounds in the weight would give the total foot-pounds lifted per minute. Dividing by 33,000 gives us the required horse-power which the engine will deliver at the belt under full load.

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